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Natural Resource Stewardship and Science

Terrestrial Vegetation Monitoring Protocol for the Arctic Alaska Network

Establishment, Sampling, and Analysis of Permanent Monitoring Plots

Natural Resource Report NPS/ARCN/NRR—2016/1214

ON THE COVER

Kugururok River, eastern Noatak National Preserve, in early fall. The red shrubs in the foreground are mostly dwarf arctic birch (*Betula nana*). Trees on the floodplain are balsam poplar (*Populus balsamifera*); many are relatively young, suggesting recent colonization of this site, which is north of the limit of spruce (*Picea*) and near the northern limit of poplars. Note the clonal nature of poplar colonization, as shown by the uniform colors within clumps. The tan colored flats in the background are tussock tundra, composed of cottonsedge (*Eriophorum vaginatum*) and low shrubs. The photograph is looking east from 68° 20.0’, 161° 22.6’ on 27 August 2009.
Photograph by: David Swanson, National Park Service

Terrestrial Vegetation Monitoring Protocol for the Arctic Alaska Network

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This report received formal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data, and whose background and expertise put them on par technically and scientifically with the authors of the information.

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Executive Summary

Vegetation was selected as a "vital sign" for long-term monitoring in the Arctic Inventory and Monitoring Network (ARCN) of the National Park Service. Vegetation in ARCN is dominated by arctic tundra and is vulnerable to alteration as a result of climate change, herbivores, disturbance processes such as fire, and airborne pollutants. This protocol presents methods for field-based sampling of vegetation monitoring plots; remote sensing is also used to monitor vegetation in ARCN but is covered under a separate vital sign "Terrestrial Landscape Patterns and Dynamics". The present protocol emphasizes monitoring of vegetation composition and structure (vascular and non-vascular) and lichen community composition. Our objective is to detect major changes in vegetation that occur at decadal time intervals. Lichens are of particular interest in ARCN because of their significant biomass and diversity, importance as forage, vulnerability to contaminants, and suitability for monitoring designs with long intervals between sampling. Vegetation plot monitoring in ARCN includes four major projects.

1) Vegetation composition and structure is monitored at a set of 24 "nodes", which are study areas chosen to be accessible and representative of major ARCN ecosystems. Sampling at the nodes consists of 11 to 29 plots, located using a stratified systematic design. Most of these plots were established in 2011-2013. Plant cover and height by species are measured by point intercept transects, and trees are inventoried on a fixed-area plot.

2) Lichen community composition is monitored at an ARCN-wide set of plots, most of which were established using a stratified random design across the Western Arctic Parklands (WEAR) in the period 2000-2007 and Gates of the Arctic National Park and Preserve (GAAR) in 2012. These plots are sampled by a modification of the nationwide U.S. Forest Service Forest Inventory and Analysis (FIA) lichen monitoring protocol, which involves producing a comprehensive species list with the abundance of each taxon estimated as one of six classes.

3) Lichen and vascular plant cover and species composition along the Red Dog Mine haul road in Cape Krusenstern National Monument. These plots were established in 2006 using a stratified random design to monitor the effects of contaminants (primarily due to dust containing heavy metals) on vegetation. Sampling consists of cover by point intercept transects and composition on 4 by 8 m plots.

4) Lichen and vascular plant cover and species composition in ungulate exclosures, established in Bering Land Bridge National Preserve in 2012. A set of eighteen, 9 by 9 m exclosures, designed mainly to exclude caribou and reindeer, were constructed at subjectively chosen representative sites with potential for moderate to high lichen cover. Sample plots identical to those in project (3) above were placed inside and outside the exclosures to separate the effects of herbivores from other causes of vegetation change.

The sampling interval for all four projects will be 10 to 15 years. Long sampling intervals are appropriate in ARCN in view of the significant expense involved in fieldwork, the slow rates of change, and absence of inter-annual variation in lichens and evergreen woody plants.

1. Background and Objectives

1.1. Importance of vegetation and prospects for change

Vegetation was identified by a collaborative process as a monitoring vital sign in the National Park Service (NPS) Arctic Inventory and Monitoring Network (ARCN, Fig. 1, Lawler et al. 2009). This decision was based on the obvious importance of vegetation as the source of ecosystem productivity and wildlife forage, combined with its vulnerability to climate change, herbivore effects, fire, and airborne pollutants. Vegetation change, in the form of an increase in shrubs, has been documented over recent decades in ARCN and is probably due to climate change (Tape et al. 2006). Treeline has also advanced, though to a lesser degree (Suarez et al. 1999). Ungulate herbivore effects on vegetation include the effects of caribou and reindeer on lichens (Helle and Aspi 1983) and ptarmigan on shrubs (Tape et al. 2010), in addition to the more familiar effects of moose on shrubs and trees. (Caribou and reindeer are conspecific *Rangifer tarandus*; “caribou” refers to wild North American animals, while “reindeer” refers to animals descended from domesticated Asian deer that were imported to Alaska in the 1890s and early 1900s, both feral animals and members of existing domestic herds.) ARCN lies within the range of three caribou herds, the Teshekpuk, Central Arctic, and Western Arctic herds (Valkenburg 1998). The latter is Alaska’s largest caribou herd and its animals have increasingly used BELA as winter range in recent years (Dau 2005). We have observed females and young indicative of calving in BELA. In addition, BELA is the only NPS unit in the U.S. with permitted reindeer herding, though in recent years reindeer have not been present on NPS units (Sparks and Thorpe, 2008). Lichens are abundant in ARCN, and they are valuable forage for caribou and reindeer, yet very slow-growing and vulnerable to overgrazing, trampling, and fire (Holt et al. 2008, Joly et al. 2009). Lichens are also vulnerable to damage from airborne pollutants (Geiser and Neitlich 2007). Heavy metal pollution of ARCN ecosystems by dust from mining activities has already occurred (Hasselbach et al. 2005) and more could occur with future development. Diversity of plants, especially lichens, has declined near an ore haul road in ARCN as a result of heavy metal pollution from dust (Neitlich et al., in preparation). In short, ARCN’s terrestrial vegetation is a foundation of the ecosystem that is changing and will continue to change.

1.2. Protocol objectives

1.2.1. Establish a set of plots that can be used to track vegetation changes at a representative set of sites across ARCN: the vegetation nodes.

These permanently marked plots are designed to 1) detect major changes in structure and composition of vegetation within deliberately selected representative areas. This includes the height and cover of vascular plants by species, tree diameters, and cover of non-vascular plants by selected species, species groups, or higher taxa. We are interested in changes that occur and persist over decadal time intervals. The plots are intended to be versatile in their ability to portray a wide variety of as-yet unknown future changes. 2) Provide information on the relationship between vegetation and soil/site properties through a comprehensive description of the soil and site. 3) Provide ground reference data for remote sensing and remote-sensing based modeling. High-resolution aerial photographs and satellite imagery of the plots will be used to calibrate plant measurements made on photographs as a part of the “Terrestrial Landscape Patterns and Dynamics” vital sign. This aspect of the program is referred to below as “Vegetation Node Sampling”.

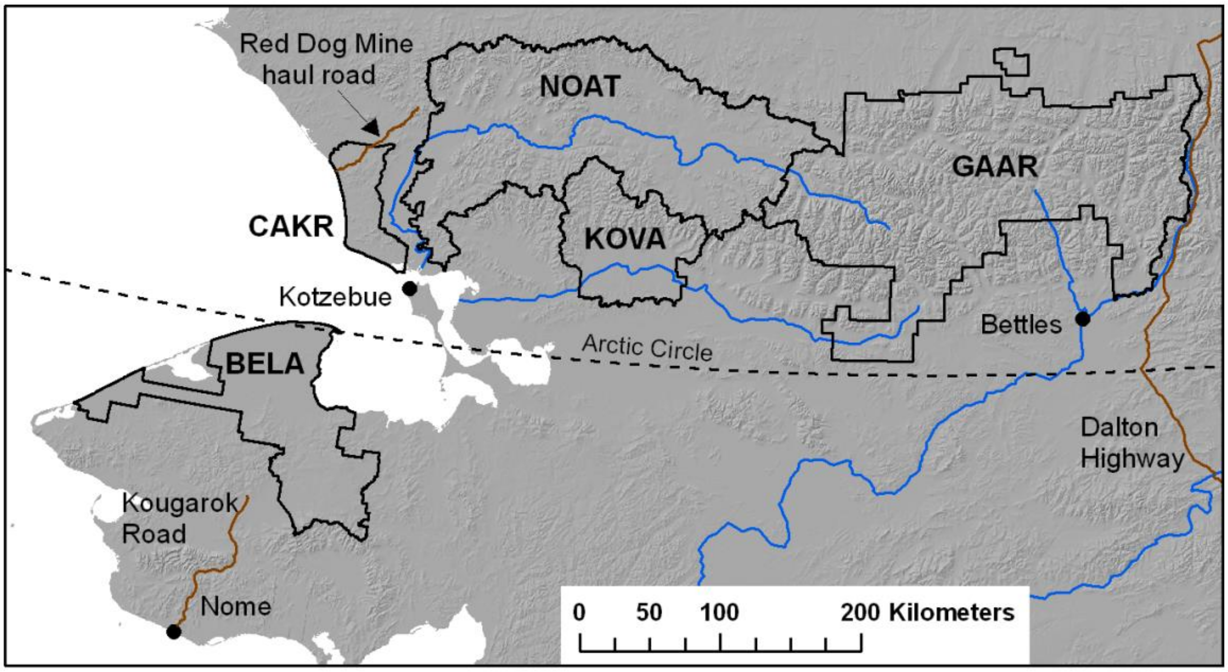

Figure 1. The NPS Arctic Inventory and Monitoring Network (ARCN). BELA – Bering Land Bridge National Preserve, CAKR – Cape Krusenstern National Monument, GAAR – Gates of the Arctic National Park and Preserve, KOVA – Kobuk Valley National Park, NOAT – Noatak National Preserve. The four western units are combined administratively into the Western Arctic Parkalnds (WEAR). The three locations with commercial and charter air services (Bettles, Kotzebue, and Nome) are shown. The Red Dog Mine haul road is the only road in the network.

1.2.2. Formalize protocols for re-sampling of existing ARCN-wide lichen community composition plots.

The objective of this study is to detect major changes in lichen community composition, diversity, and abundance. ARCN has an existing set of lichen community composition plots that were established by probabilistic design in the four western ARCN parks during the period 2003-2007 (Fig. 2; Holt and Neitlich 2010a,b) and partly probabilistic design in GAAR in 2012 (Nelson et al. 2015). These plots have all been sampled once at the time of this writing (2015). They were sampled using the national FIA lichen monitoring protocol (USFS 2011), with some adaptation to arctic conditions that are documented here. Data gathered include community composition and diversity in relation to environmental gradients such as climate, landform, and herbivory. These plots are a valuable resource for tracking lichen community composition changes. This aspect of our monitoring program is referred to below as “ARCN-wide Lichen Community Composition Sampling”.

1.2.3. Formalize protocols for re-sampling of existing Red Dog Mine haul road monitoring plots

The objective of this study is to monitor the effects of the Red Dog Mine haul road on vegetation, especially lichen species composition. Lichens are both ecologically important and sensitive bio-indicators. These lichen plots were established in 2006 along the Delong Mountains Transportation System (DMTS), the 32 km of road that passes across the northern part of CAKR between the Red Dog Mine and the Red Dog Port Site on the Chukchi Sea (Fig. 3). These plots, which have been sampled once at the time of this writing (2016), document a gradient in effects of heavy-metal contaminated dust on vegetation, especially lichen community composition. Impacts range from heavy contamination near the road to minimal more than 1000 m away and close to background levels at 2000 m (Neitlich et al., in preparation; Hasselbach et al. 2005). The study is a companion to monitoring of metal contamination under the ARCN vital sign "Wet and Dry Deposition", which monitors the elemental concentrations of metals, S, and N in the moss *Hylocomium splendens* at the same locations and had sample events in 2001 and 2006. Continuing vegetation change is expected due to ongoing use of the road, changes in truck design implemented to reduce dust, and proposed new mining developments. Our goal is to monitor as long as additional impacts are possible (i.e. as long as the road remains in service). If the road were to be decommissioned, monitoring should continue with declining intensity over time to track recovery. This aspect of the ARCN vegetation monitoring program is referred to below as "Red Dog Mine haul road monitoring".

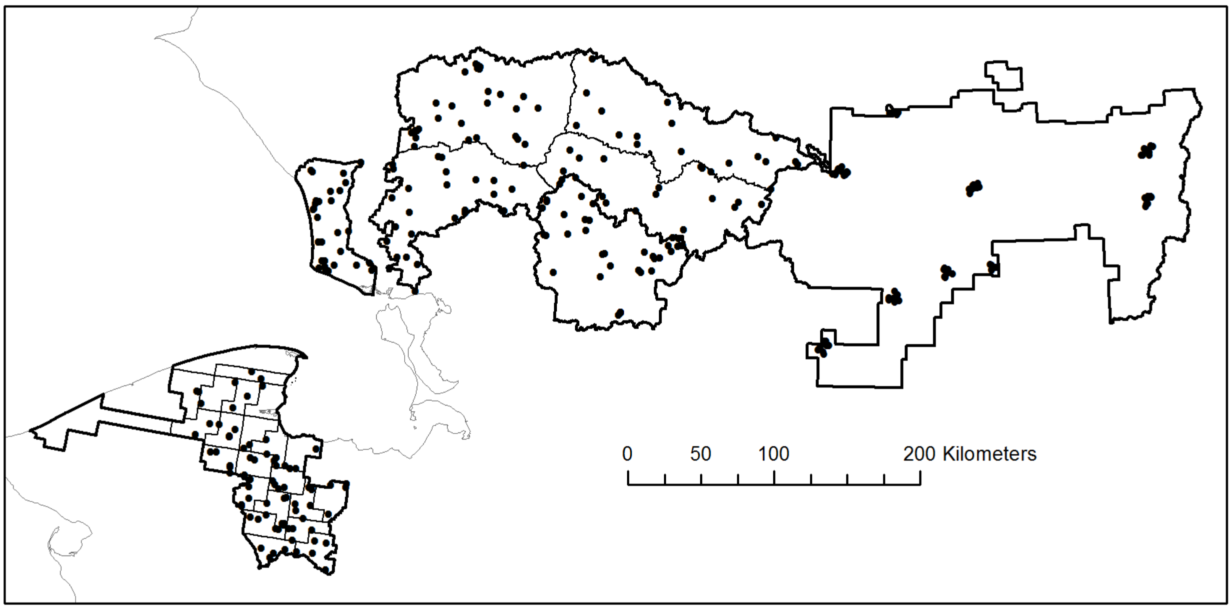

Figure 2. ARCN-wide lichen community composition long-term monitoring plot locations, 2003-2007 in WEAR and 2012 in GAAR. Heavy lines separate NPS units, fine lines separate supplemental blocks used to further distribute samples in NOAT and BELA. See Fig. 1 for NPS unit names and abbreviations.

1.2.4. Formalize protocols for establishment and sampling of ungulate grazing exclosures in BELA

The purpose of this project is to provide an ungrazed reference, against which we may judge the long-term effects of ungulate grazing on lichens. BELA's enabling legislation provides for long-term reindeer grazing, provided that range management practices that do not degrade resources. Though domesticated reindeer have not been present in BELA in recent years (partly as a result of competition with wild caribou that have begun to use the preserve in increasing numbers), NPS remains responsible for proper grazing land management in the future. Analysis of the lichen composition monitoring plots in BELA described in section 1.2.2 above showed that we lack reference conditions for ungrazed winter range in this area, and that the only way to develop this would be by construction of a set of ungulate exclosures. These exclosures were set up in 2012. They are free-standing, 9.1 by 9.1 m (30 by 30 ft) square fenced areas. This fencing is not subject to frost heave and requires no soil disturbance (Fig. 4). Exclosures are distributed among major lichen-dominated cover types in the southern half of BELA, where most suitable winter range is located. Monitoring plots were established inside and outside of the exclosures.

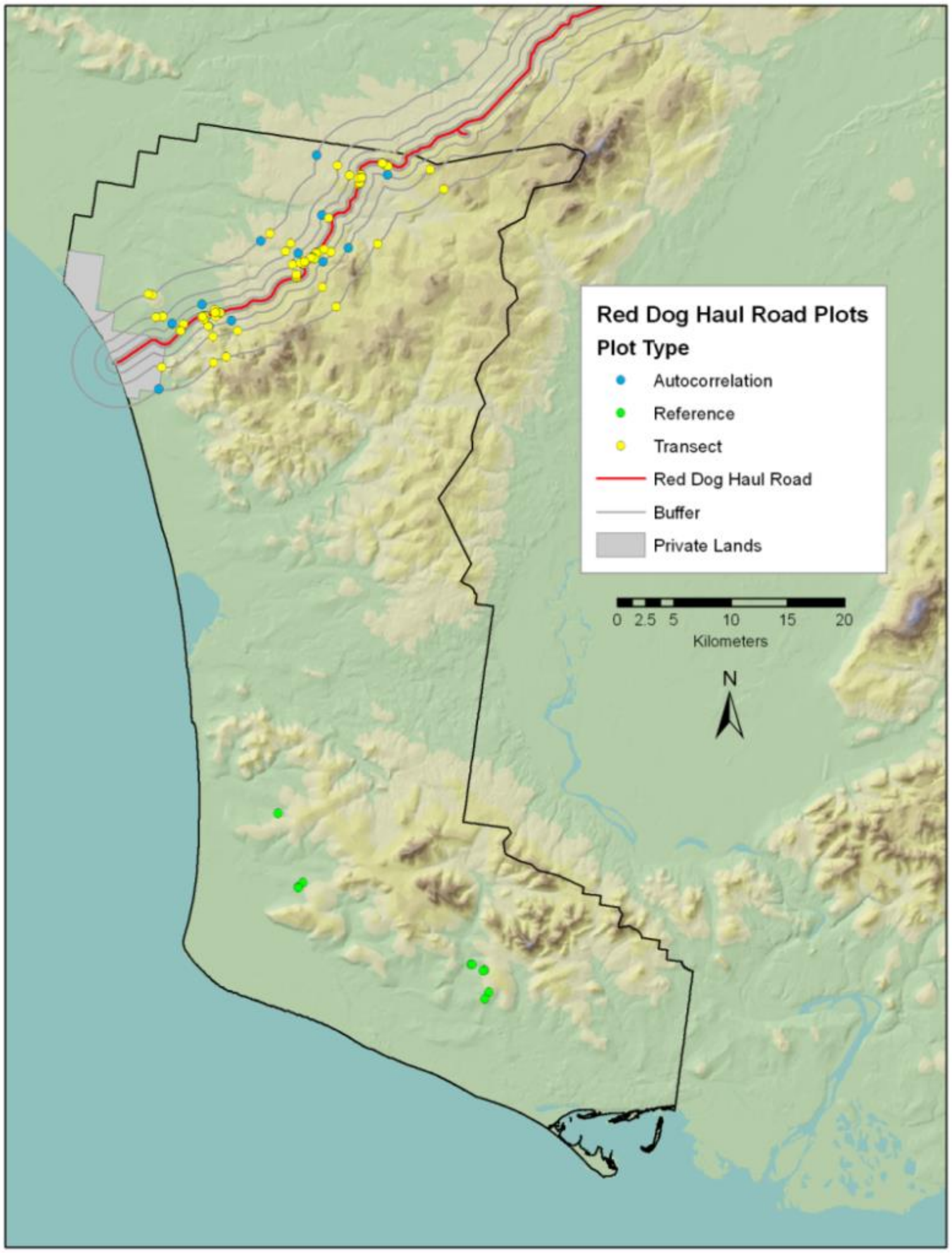

Figure 3. Red Dog Mine haul road monitoring plots.

1.3. Limitations to sampling in ARCN and their implications

ARCN occupies over 20 million acres, about one-fourth of the entire area of NPS-administrated lands in the United States (Fig. 1). There is only one developed road in the network, the Red Dog Mine haul road (or Delong Mountain Transportation System, DTMS), 75 km (47 miles) long and itself accessible only by air or boat. Access to ARCN typically requires a commercial flight to a nearby community followed by a charter flight of up to an hour or more to sample sites within the park. All landing sites in the parks are undeveloped, i.e., a lake, river, river gravel bar, etc. and thus are subject to additional takeoff and landing hazards. Most of the network is designated or eligible wilderness, and air traffic is one of the main impacts on wilderness values. Finally, one of the most important vegetative life-form groups – lichens – is highly vulnerable to damage by trampling during sampling. In short, access to monitoring sites in ARCN is expensive, highly fuel-consumptive, hazardous, and potentially damaging to park wilderness values and to the vegetation on the plots themselves. These limitations have led us to several compromises regarding vegetation sampling design.

Figure 4. Design of a BELA ungulate exclosure. The unit consists of six 3 m by 1.8 m (10 ft by 6 ft) fence panels that are clamped together and free-standing, without any posts driven or buried in the soil.

1.3.1. Remote sensing will be utilized where possible.

Remote sensing can be used to detect both long-term trends involving structural changes such as tree or shrub encroachment, and year-to-year variations in plant productivity as shown by vegetation "greenness" indices (Stow et al. 2004). Remote sensing has very limited capability to track trends in vegetation composition, beyond what can be inferred from the structural changes. Remote sensing of vegetation is covered under a separate ARCN vital sign, “Landscape Patterns and Dynamics”. The “Terrestrial Vegetation” vital sign is in part designed to provide ground verification for remote sensing of vegetation under the “Landscape” vital sign, which should improve the effectiveness of the latter.

1.3.2. Existing plots will be utilized where possible

A variety of vegetation plots suitable for long-term monitoring are already present in ARCN. The existing lichen community composition plots (sections 1.2.2 and 1.2.3 above) represent a significant investment and provide us with a 5- to 10-year head start on a time series for change detection, relative to new plots that were established as a part of this protocol.

1.3.3. Vegetation plot re-sampling will be infrequent

The impact and cost considerations described above, plus the generally slow rates of change in arctic vegetation, led us to choose long sampling intervals. Previous monitoring in or near ARCN using vegetation plots (Suarez et al. 1999, Jandt et al. 2008, Villareal et al. 2012) and aerial photographs (Tape et al. 2006, Swanson 2013) show that vegetation change can take decades to be detectable. Vegetation monitoring in the Central Alaska Network (CAKN, Roland et al. 2004 and C. Roland, personal communication, 2015) has shown undisturbed tundra vegetation to change little in a 5- to 20-year time span, which guided the decision by CAKN personnel to re-measure of plots at intervals of more than 10 years. Thus for the vegetation nodes and Red Dog Mine haul road plots, we suggest a 10 year re-sampling interval. These plots are relatively inexpensive to reach because they are in clusters accessible by fixed-wing aircraft (the vegetation nodes) or fixed-wing aircraft plus road (the Red Dog road plots). The vegetation nodes are a high priority because they involve comprehensive sampling of all aspects of vegetation, and the Red Dog plots because they monitor an important industrial impact area. The lichen exclosure plots are also relatively inexpensive to re-sample, because there are just 18 exclosures and all are within about 100 km of a road-accessible helicopter staging area. Given the slow rate of change expected for the exclosure plots, the recommended resampling interval is 10 to 15 years.

For the more expensive network-wide lichen community composition plots, we suggest an opportunistic re-sampling program that will be adapted to funding availability and priorities in the future. These plots are more expensive to reach because, in all the NPS units except GAAR, the plots are accessible only by helicopter and dispersed such that a flight is required for each plot. Ideally, a statistical subsample of these plots would be sampled once every 15 years.

The greatest difficulty introduced by long sampling intervals is reduced ability to detect long-term trends in plant groups that show significant year-to-year variation relative to long-term trends. A good example is the canopy cover of herbaceous plants, which can be reduced by cold weather or herbivores one year and return to former levels the next. A recommended way to deal with this issue is to collect data at short time intervals so that the short-term variation can be quantified. However, given the costs, impacts, and hazards that sampling entails, we have chosen *not* to attempt to quantify short-term variation in ARCN, and we recommend re-sampling only at intervals long enough that we could reasonably expect long-term trends to be manifested. The issue of short-term variability will be dealt with in the following ways: 1) we will emphasize the components of vegetation with minimal short-term variability. The cover and mat thickness of nonvascular plants (mosses and lichens), cover of evergreen perennial plants, basal cover of long-lived perennials (e.g., tuft-forming graminoid species), height of woody plants, and diameter of tree boles change more gradually through time, with minor seasonal fluctuations; if a rapid change occurs (most often by fire), the effects of the change persists for many decades. Thus measurements of these properties are well suited to monitoring by infrequent visits. Lichens are given special emphasis in our sampling program as a result of their suitability for infrequent re-sampling, their importance as forage for caribou and reindeer, their great abundance and diversity in ARCN's tundra ecosystems, and their sensitivity to contaminants. 2) We will rely on our relatively large sample sizes to compensate for inter-annual variability and sampling error. Vegetation node sampling is distributed over a large area and over 3 growing seasons in each sampling cycle, and statistics calculated across this sample will be relatively insensitive to local herbivory events or single years with unusual weather. 3) We will use caution in interpreting the results of cover data by species for herbaceous species (see SOP #8, part B5).

1.3.4. New Plot Locations 2010-2014

Fixed-wing air access points are mainly lakes suitable for floatplane landings and river gravel bars suitable for wheel plane landings. These are generally well distributed across ARCN and provide access to all major environments. An economical sampling approach involves shuttling a crew to a fixed wing access point, where they establish a camp and sample for several days to a week, and are then shuttled to another location. However, a sampling design based on fixed-wing access points removes much of ARCN from the sample population and thus eliminates simple design-based statistical inference for ARCN as a whole.

A completely probabilistic design requires helicopter access to most plots. This approach is considerably more expensive because helicopter time is more expensive than fixed-wing time of comparable capacity, and also because flight time is required between nearly all plots. Furthermore, though both helicopters and airplanes are motorized vehicles with potential conflicts with wilderness values, airplanes are permitted in wilderness in ARCN NPS units under (ANILCA 1980), while helicopters require additional clearances under park NEPA compliance regulations and are not generally permitted in GAAR. Another logistical issue is that intensive helicopter use in the distant parts of ARCN requires establishment of remote fuel caches. Thus new plots were clustered around fixed-wing access points. Some helicopter-access plots may be added in the future, but they will probably limited to places that are relatively near to fuel sources and in non-Wilderness, such as CAKR and parts of KOVA.

2. Vegetation Node Sampling

The ARCN vegetation nodes are a set of deliberately chosen study areas, with centers defined by an air access point and a suitable base campsite, and radius defined by feasible daily foot travel from the base camp. The area within each node is stratified by physiographically-defined landscape ecological units (referred to henceforth as "physiographic strata"), and plots are located within each stratum by a systematic scheme with random start.

2.1. Node location, number, and physiographic strata

ARCN vegetation monitoring nodes were chosen deliberately, by expert opinion of the Vital Sign lead, through consultation with the ARCN Technical Committee and outside experts. Given that nodes are relatively few and highly constrained by access, we opted for maximum control over node locations to ensure coverage of the full range of ARCN environments.

This sampling scheme is in contrast to the probabilistic schemes adopted in the NPS Central Alaska Network (CAKN, Roland et al. 2004) and the Southwest Alaska Network (SWAN, Miller et al. 2010). The consensus among ARCN technical committee members and collaborators is that the network should not attempt to implement a new probabilistic vegetation sampling scheme, for the reasons described in section 1.3 above. The probabilistic sampling scheme employed in CAKN (which is similar in size to ARCN) depends on several conditions that do not apply in ARCN: 1) a road system in or near all park units, 2) omission of large areas from sampling, including extensive high-altitude rock and ice (lacking in ARCN) and areas south of the Alaska Range in Denali National Park and Preserve and south of the Chugach Range in Wrangell-St. Elias National Park and Preserve, and 3) greater funding priority of vegetation monitoring relative to other vital signs in CAKN. Helicopter access was irreplaceable during the initial vegetation and botanical inventories of ARCN (Parker 2006, Jorgenson et al. 2009), but, as described previously, we have chosen not commit the NPS to repeated intensive helicopter campaigns in ARCN in the future.

Factors taken into account in the choice of node locations include:

- Accessibility by fixed-wing aircraft. Helicopter access may be considered in the future for high priority locations, non-wilderness, and less remote areas that can be reached with relatively short flights that do not require fuel caching.

- Distribution across major environmental gradients. The major gradients considered include mean annual temperature, major landforms and geology, elevation, biome (forest vs. tundra), and distance from the ocean.

- Distribution across NPS units. All NPS units have at least 2 nodes.

- Inclusion of significant natural features. Natural features that were key to the recognition and establishment of the NPS units (e.g., the Great Kobuk Sand Dunes) or are recognized to be of special importance (e.g., coastal environments) were targeted for node establishment.

- Access to at least 2 local physiographic strata (and preferably 3 or 4; see below for more explanation of the physiographic strata). For example, a potential node with foot access to tussock tundra lowlands, floodplain scrub, and rocky mountain slopes was chosen ahead of a potential node with access only to tussock tundra lowlands.

The latter two criteria resulted in "over-sampling" of rare environments. For example, we have 13 plots (2.8% of all plots) in coastal salt marsh, while these marshes are estimated by Jorgenson et al. (2009) to cover less than 0.1% of ARCN. This selection bias is corrected by post-stratification, as described in section 2.4 below.

The final number of nodes and their exact placement were determined by adaptive process during the course of sampling. The total number of nodes was determined by expert opinion about the number needed to cover major ARCN ecosystems, combined with considerations of operational efficiency. Based on discussions with technical committee members and outside experts, approximately 25 nodes, each containing about 20 plots and covering 2 to 5 physiographic strata, sampled with a return interval of 10 to 15 years, would provide good representation of major ARCN ecosystems. As of 2016 we have 24 nodes with 78 transects and 471 plots, and we have concluded new plot establishment.

An example of a typical node with the physiographic strata "limestone barrens", "shrub terrace", and "non-carbonate mountains" is shown in Fig. 5. These strata are "ecological units" at the level of Landtype in the National Hierarchical Framework of Ecological Units (Cleland et al. 1997). Landtypes typically occur in patches of one to a few square km on the landscape and consist of a mosaic of vegetation types across a common landform. Maps of Landtype are not likely to become available in the foreseeable future across ARCN. Maps of Ecological Subsection – two levels above Landtype in the hierarchy – are available for ARCN (Boggs and Michaelson 2001, Jorgenson 2001, Jorgenson et al. 2001, and Swanson 2001a, b).

The physiographic strata differ from the ARCN "ecotypes" mapped by Jorgenson et al. (2009). The latter are cover types mapped using 30-m resolution satellite imagery in combination with other data. A physiographic stratum at a vegetation node covers a larger area (e.g., square kilometers in size), defined primarily by soil and landform criteria, and contains a mosaic of different ecotypes. Examples of similar the physiographic strata were sought at multiple nodes, e.g. limestone uplands were sampled at 3 nodes, though the physiographic strata are locally defined, and each one is essentially unique. The physiographic strata were established primarily to guide dispersal of transects across the variety of environments at a node, and not as strata for data analysis. The ecotypes of Jorgenson et al. (2009) have been mapped ARCN-wide under a single legend and are used to post-stratify the vegetation node samples, but they were not used to select plot locations. The ecotypes of Jorgenson et al. are more suitable as analytical strata than the physiographic areas, because they are available as an ARCN-wide legend with areal estimates that can be used as weights, and because they have narrow definitions that greatly reduce the within-strata variances in plant characteristics.

2.2. Plot placement and number within a node

The size of the node was determined by the maximum reasonable distance traversable in about 2 hours by foot or boat from the basecamp/access point, such that the majority of each day is available for actual sampling. The major physiographic strata within this access perimeter were readily identified on high-resolution imagery (Fig. 5). The nearest example of each physiographic stratum to the campsite that was large enough to accommodate a sample transect was identified, and a proposed transect starting point and azimuth located within it (Fig. 5). Most transects locations were selected in the office prior to fieldwork. We attempted to place transects in all of the accessible physiographic strata (landtypes) at a node.

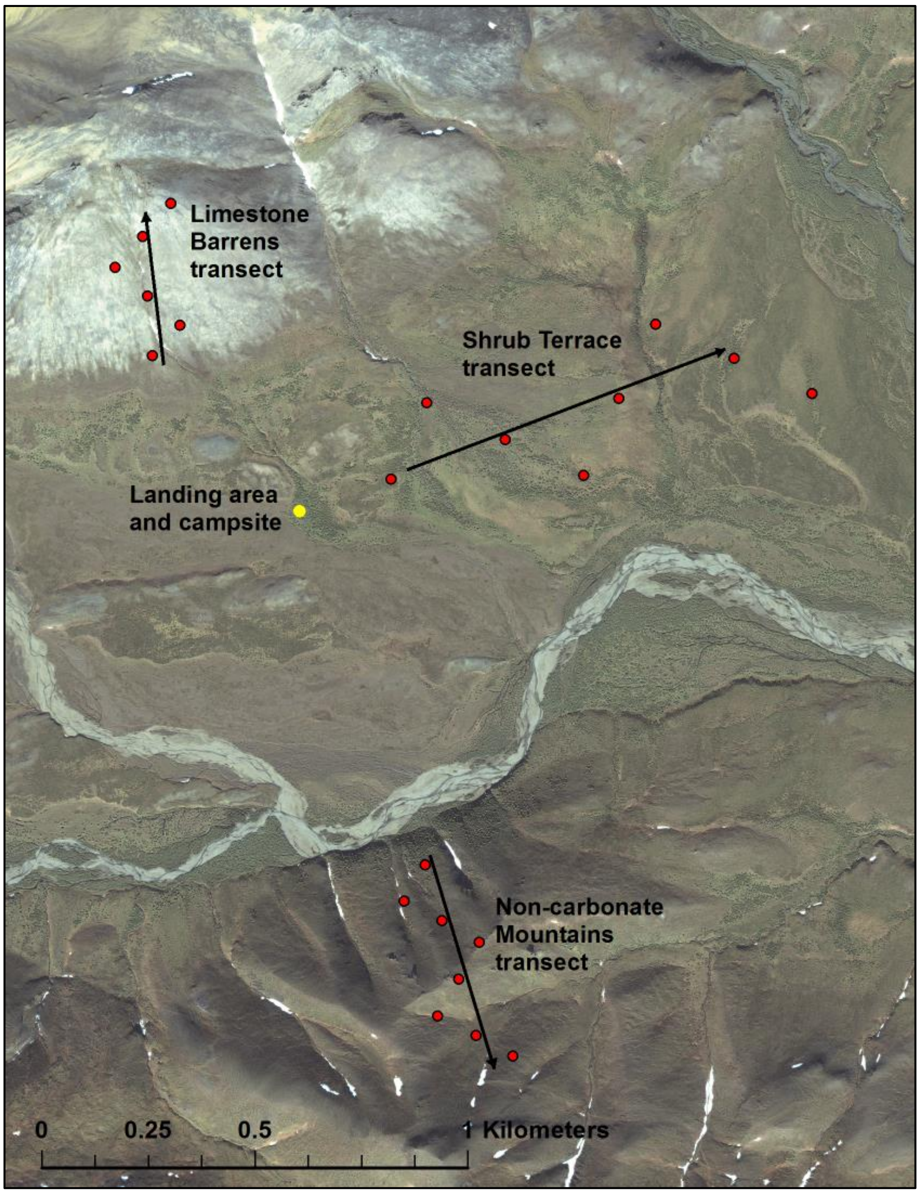

Figure 5. An example ARCN vegetation monitoring node (Copter Peak, NOAT). The locations of the 3 transects sampled, are shown, along with the campsite, which is located near an undeveloped landing strip.

The actual transect start and direction were randomized, within specific limits, near the proposed transect location to avoid forcing the transect across terrain obstacles or multiple strata (Fig. 6). Plots were spaced systematically along the transect. Transects are efficient relative to randomized plot locations in terms of the time spent sampling vs. traveling. However, strictly linear transects have drawbacks, including (1) bias when they align with linear natural features (a problem with small samples even if azimuths are randomized), (2) inefficiency arising from passing by suitable sample areas on the way to a distant transect end, and (3) demand for repeated travel over the same route if a transect takes more than one day to complete. A zig-zag layout reduces these problems by changing the orientation of the transect at regular intervals and distributing sample points over a swath of territory. The zig-zag transect configuration mimics the highly efficient free transect design used in inventories (e.g., Swanson 1995, Jorgenson et al. 2009).

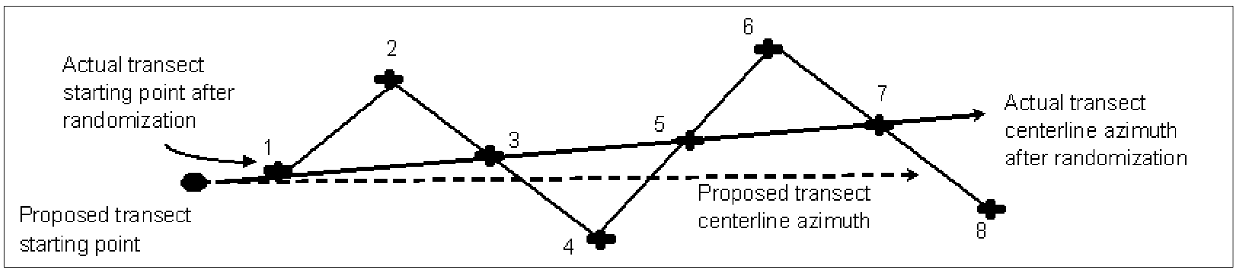

Figure 6. Vegetation node transect layout. The proposed transect starting point and proposed transect azimuth are chosen deliberately to pass over an accessible portion of a physiographic stratum. The actual transect starting point and centerline azimuths are chosen by randomization. Plots are indicated with a cross and their spacing is 100 to 200 m.

Our standard plot spacing is 200 m, which results in a sampling swath about 280 m wide and 1 km long for 8 plots. In complex landscapes or situations where a shorter length is available, the plot spacing was reduced to 100 m or, in a few cases, 50 m.

The number of plots per physiographic stratum was chosen as follows. Crews could usually complete 4 plots per day. Travel time to each transect was often significant, but travel time between plots on a transect was not. Hence it was most efficient to spend either one entire day (4 plots) or 2 entire days (8 plots) per transect. Typically one can travel one-half to several kilometers in a unit before crossing out of it or reaching an obstacle such as a lake or river. Thus a zig-zag transect described above with 4 to 8 plots could be accommodated in a typical physiographic stratum. Since most nodes have 2 to 4 physiographic strata available, the crew can devote 1 or 2 days per stratum and complete about 20 plots in about 5 days; this provides a break associated with the move to a new node at convenient (weekly) intervals.

Our subjective impression was that in most physiographic strata 4 plots provided a minimal sample while by the 8th plot they were becoming redundant. This picture of the marginal gain in information added by additional plots was supported by analysis using the method suggested in McCune et al. (2002), a variation of the species-area curve technique that takes abundance information into account (Fig. 7). If we take all transects sampled to date with 8 or more plots, the centroid value (mean cover of each plant) for the first 4 plots had an average similarity of 0.82 (on a scale of 0 to 1) to the centroid obtained for all 8 plots. The similarity of the first 7 plots together to the final set of 8 was, not surprisingly, quite high (0.94), indicating that the overall picture of the physiographic stratum obtained by plot 7 was changed little by addition of the 8th plot, and additional time would indeed be better spent on a new transect.

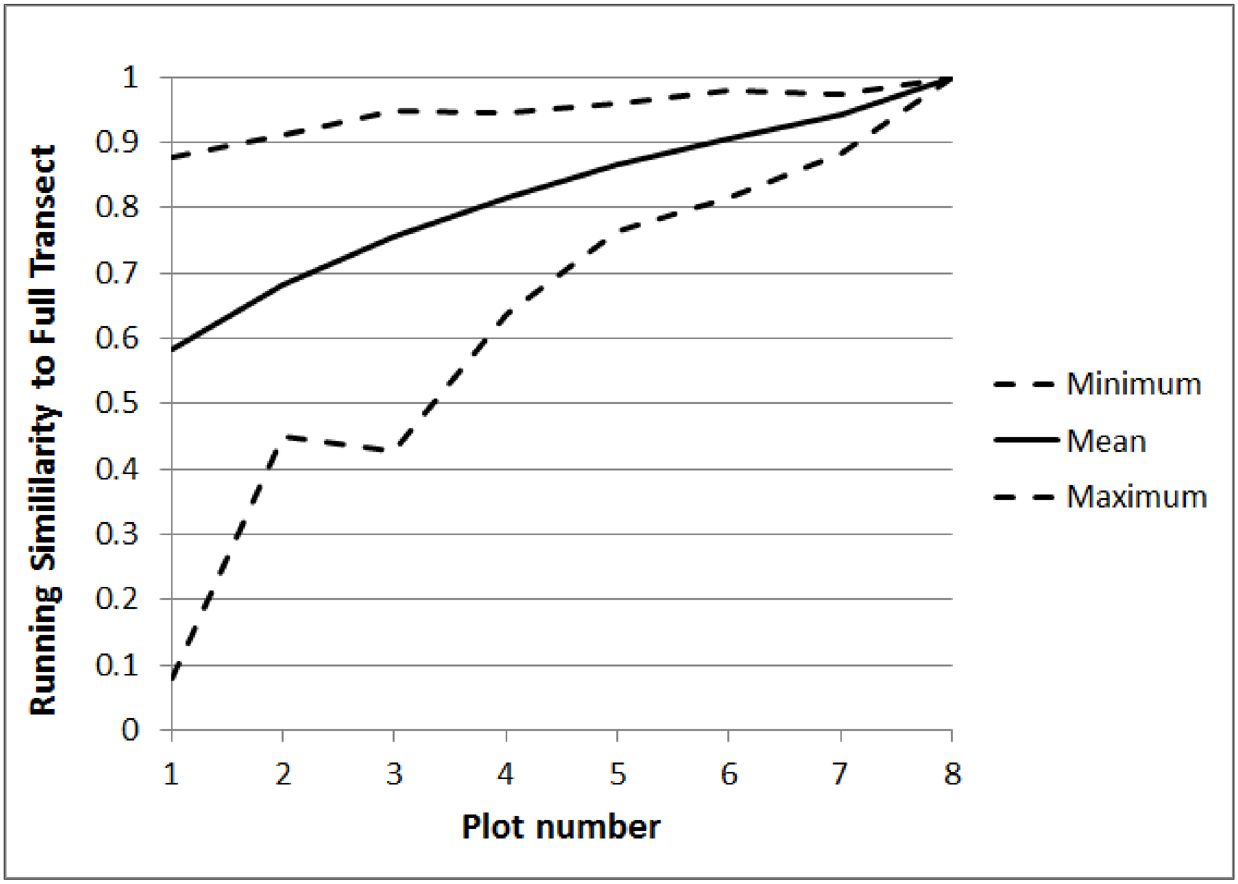

Figure 7. Marginal gain in information provided by each plot up to 8 on a transect. All transects with 8 or more plots in the study were included (22 transects). The running mean of all plant cover values on the plots (the centroid) was computed on each transect, progressively adding plots in the order they were sampled (i.e. plot 1, plots 1 and 2, plots 1 through 3, plots 1 through 4, etc. up to all 8 plots). The Sørenson similarity index of each intermediate sample centroid was compared to the centroid for all 8 plots (McCune et al. 2002). The minimum, mean, and maximum similarity of the running mean values to the final for all 8 is shown for the 22 transects.

Clustering of samples, such as our plots are clustered within a transect, often results in a correlation between samples within clusters. This is known as the "design effect" (Kish 1965), and it reduces the effective sample size. A correction for design effect in a sample can be computed from the data, in our case with the "survey" package of R statistical software (Lumley 2004, 2014). There is a trade-off between time saved per sample (plot) by clustering of samples, and the resulting reduction of effective sample size. The design effect is different for each plant species and each post-stratum (i.e. there are thousands possible, too many to analyze here). But the great efficiency of sampling plots on a transect and our experience with encountering new kinds of vegetation in a mosaic along these transects has convinced us clustering of plots based on one or two days of work is well worth the potential reduction in effective sample size.

The protocol also allows for deliberate placement of plots in areas of special interest that are unlikely to be captured by the systematic design, such as unique and distinctive vegetation types.

2.3. Plot layout and sampling

The plot layout (Fig. 8) generally follows the NPS Central Alaska Inventory and Monitoring Network (CAKN) protocol (Roland et al. 2004), which is in turn based on the U.S. Forest Service Forest Inventory and Analysis plot (USFS 2012). The main data elements are point intercept measurements of plant cover and height, listing of vascular plant species not encountered by point intercepts, tree measurements by standard forestry methods (diameter and breast height), and site geomorphic and soil characteristics. Point-intercepts are taken at 100 points per plot, which converts conveniently to percent cover. This number of intercepts can be completed in approximately 1 hour, after which the move to a new plot provides a welcome break. Plant point-intercepts are identified to species for vascular plants and to a set of 48 taxa for non-vascular species. These non-vascular taxa were chosen to be rapidly recognized by field personnel with a moderate amount of training and include species of common and readily recognized ground-covering mosses and lichens, and selected genera and species groups; 7 life-form classes (e.g., "Lichen, foliose") are available for species not on the list or unknowns. Point-intercept measurements include the height class of the uppermost intercept of each species. Plant percent cover times height correlates well with aboveground biomass for both vascular and nonvascular plants, and with leaf area index of vascular plants in arctic environments (Chen et al. 2009). Both cover and height can be measured with good repeatability using a laser point-intercept apparatus (Fig. 9) developed for the NPS Southwest Alaska Network's coastal monitoring protocol (Jorgenson 2009). Point intercept and thickness measurements of lichens are well correlated with biomass (Moen et al. 2007, Rosso et al. 2014).

Plot centers are permanently marked with a buried magnet that can be relocated by GPS combined with a magnetic detector. The point-intercept lines are aligned with the magnetic cardinal directions, following the CAKN protocol (Roland et al. 2004). The use of magnetic azimuths eliminated potential errors due to mis-correction for magnetic declination during the initial sampling cycle; declination is different at each node and adjustments are prone to errors. Our experience suggests that most observers agree on magnetic azimuths within about ±2°. If magnetic declination changes in the future more than this amount, a correction for this change will be needed to reduce the difference in location between the original and repeat transects locations. The point-intercept measurements are a sample, and exact re-location of transects is not crucial or even possible.

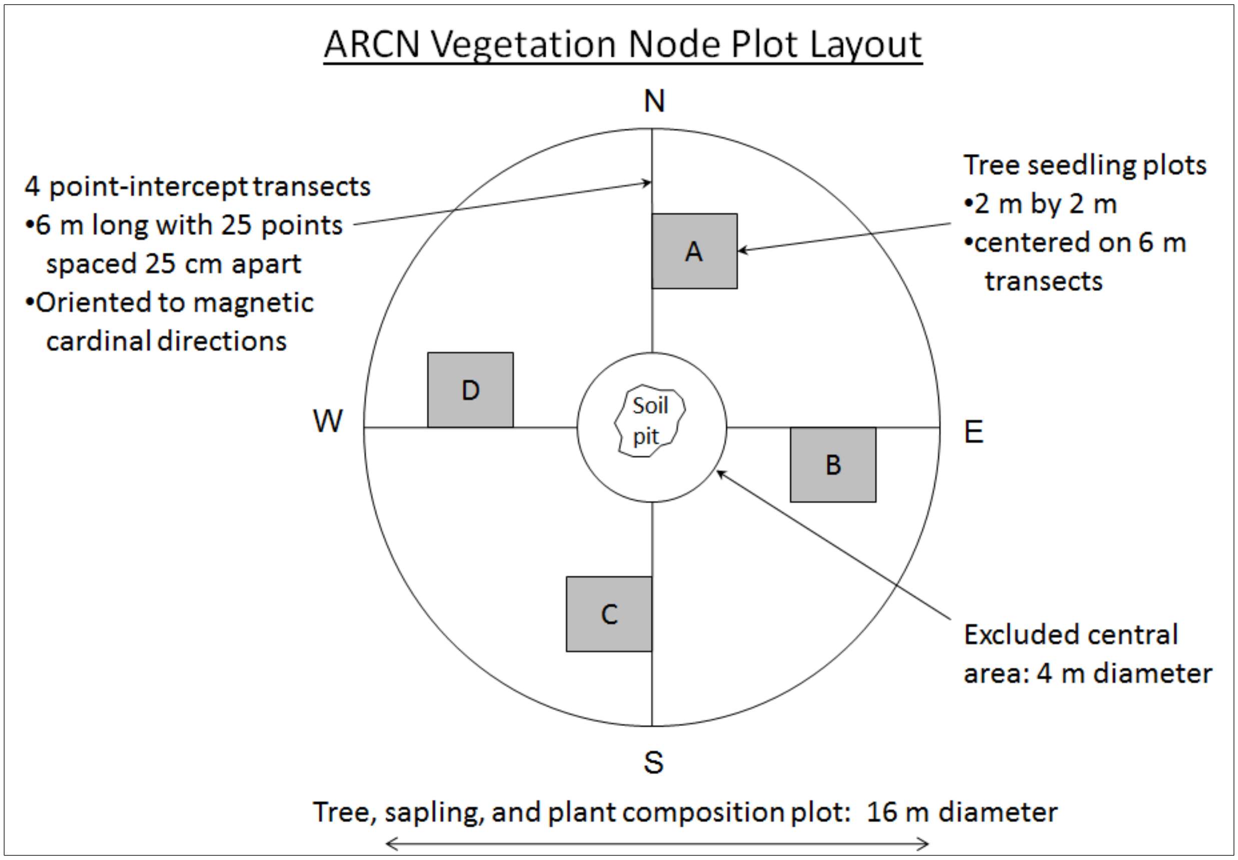

Figure 8. Vegetation node plot design.

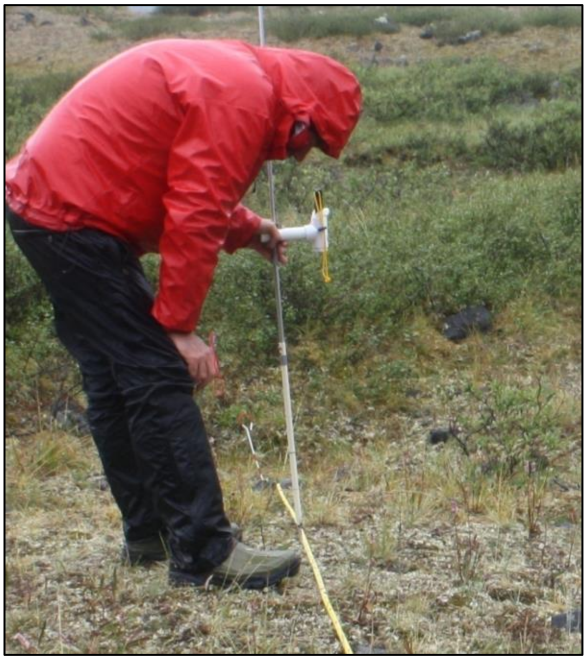

Figure 9. Laser device for point-intercept measurements. A waterproof laser pointer (designed for underwater applications) is secured to a metal rod with PVC pipe fittings. The rod is placed a measuring tape at 25-cm intervals, and the species and height of plants intercepting the laser are recorded.

Plot photography includes multiple panoramic shots from the plot center and periphery, plus a series of overlapping photos taken from a tall pole that can be used to assemble an aerial mosaic of the plot. Site characteristics recorded at each plot include slope steepness, slope azimuth, slope curvature, major and minor landform, and patterned ground. Landform descriptions follow the system designed for USDA-NRCS soil surveys (Schoeneberger and Wysocki 2012).

2.4. Data management, analysis, and reporting

The data are appended annually to a relational database at the end of each field season. This database is maintained on a server at the NPS office in Fairbanks, Alaska (see Appendix B SOP #7 for details).

The basic measures that can be derived from the sampling at each node plot includes: plant cover by species (or nonvascular species group); plant canopy volume (cover times height); non-plant ground cover proportions (litter, rock, bare soil, etc.); tree and sapling basal area by species; tree, sapling, and seedling density by species; and lichen biomass estimate (Rosso et al. 2014). The difference between any one of these measures at two sample dates on a single plot is our basic measure of change. These differences would typically be normalized by the number of years separating the two samplings, since the re-sampling time gap could vary by a few years between nodes.

Post-stratification is used to correct for the sample selection bias introduced by the deliberate choice of node and transect locations. Post-stratification is a classification assigned to each plot after sampling, based on the sample properties (Little 1993). The area occupied by each post-stratification class is known (typically from an ARCN-wide GIS layer), and these areas are used to weight the samples. This weighting can be used to correct for the fact that our deliberately chosen sample locations (as well as chance) resulted in counts of plots that are not in proportion to their actual abundance on the landscape. The ARCN ecotypes (Jorgenson et al. 2009) will probably be our most useful post-stratification system. Ecotypes are vegetation or land-cover types, mapped using satellite imagery and other data.

For example, the ecotype "Alpine Dryas Dwarf Shrub" is represented by 32 plots on 11 transects at 7 different nodes that are well distributed across ARCN (Table 1). We can make a reasonable argument that these plots provide a representative sample of the ecotype "Alpine Dryas Dwarf Shrub", and that the un-sampled parts of ARCN represent data for this ecotype that are "missing at random" (Rubin 1976). Ecotypes sampled at a minimum of 5 nodes and 18 plots are labeled "A" in Table 1; these are type for which we may be able to make individual statements about plant characteristics and changes. Ecotypes present at 3 or more nodes are labeled "B". While inadequate to say much about these ecotypes individually, these samples can be weighted by ecotype area and merged with the "A" and other "B" plots to compute statistics for these larger groups. The "A" and "B" ecotypes together cover about 87% of ARCN.

Ecotypes present at just one or two nodes represent various situations. The "C" Ecotypes in Table 1 are dispersed widely across ARCN but have small total area and thus were rarely encountered. These ecotypes could be included with "A" and "B" groups in a merged analysis, with little effect on the overall results due to their rarity. The "D" Ecotypes are not particularly rare, but are difficult to access and thus were under-sampled. These are ecotypes for which we need to look for other methods (e.g., remote sensing) to monitor change. The "E" ecotypes are localized, unique environments that were targeted for sampling. While our samples of these latter types are small, the density of plots in these ecotypes was actually quite high (note small values for "area per plot" in Table 1). Our samples of these ecotypes should be treated as index sites or case histories of these interesting and valuable ecosystems. The "Upland Mafic Barrens" ecotype (lava beds in BELA) is also of this type, but was unfortunately not well sampled. The "F" ecotype "Riverine Barrens" was not sampled, due to its lack of vegetation and the difficulty in maintaining plot markers due to flood erosion and deposition.

As mentioned above, our sampling design involves clustering of plots in space; plots within a single transect are spatially auto-correlated, and treating them as independent samples in a statistical analysis would overstate our sample size and degrees of freedom. Clustering is common to many types of sampling, and computational methods to deal with its effects are available in the R statistical package "survey" (Lumley 2004, 2014). In short, the within-cluster and between-cluster variances are used to estimate the variance of the population (i.e. the variance that would be obtained by simple random sample), and the result is used to adjust statistics such as the standard error and t-test probability.

Table 1. Count of nodes, transects, and plots in ARCN ecotypes.

Ecotype[1]	Sample Adequacy Code[2]	Count of Nodes	Count of Transects	Count of Plots[3]	Area, % of ARCN[4]	Area per plot, km^2;[5]
Alpine Acidic Barrens	A	6	8	18	9.23	445
Alpine Alkaline Barrens	B	3	3	9	3.83	369
Alpine Dryas Dwarf Shrub	A	7	11	32	15	407
Alpine Ericaceous Dwarf Shrub	A	6	12	28	2.08	64
Alpine Mafic Barrens	D	0	0	0	1.31	-
Alpine Wet Sedge Meadow	B	4	5	7	0.71	88
Coastal Barrens	E	1	1	2	0.11	48
Coastal Brackish Sedge-Grass Meadow	E	1	2	13	0.07	5
Coastal Crowberry Dwarf Shrub	E	2	2	6	0.06	9
Coastal Dunegrass Meadow	E	1	1	4	0.02	3
Lowland Alder Tall Shrub	C	1	1	2	0.7	304
Lowland Birch-Ericaceous-Willow Low Shrub	A	13	16	34	3.42	88
Lowland Black Spruce Forest	B	3	5	10	1.53	133
Lowland Ericaceous Shrub Bog	B	4	5	9	1.09	105
Lowland Sedge Fen	A	9	10	23	1.32	50
Lowland Willow Low Shrub	B	5	5	8	0.94	102
Riverine Alder or Willow Tall Shrub	B	5	5	11	0.61	48
Riverine Barrens	F	0	0	0	0.65	-
Riverine Birch-Willow Low Shrub	C	1	1	1	0.60	526
Riverine Dryas Dwarf Shrub	B	3	3	8	0.15	16
Riverine Poplar Forest	C	2	2	6	0.08	12
Riverine Wet Sedge Meadow	C	1	1	8	0.44	49
Riverine White Spruce-Poplar Forest	C	2	2	4	0.06	12
Riverine White Spruce-Willow Forest	B	4	4	9	0.48	46

[1] Ecotypes are vegetation soil units mapped at 30-m pixel resolution in ARCN by Jorgenson et al. (2009).

[2] Assessment of sampling adequacy, see text for more explanation. A – well sampled ecotypes, with at least 18 plots at 5 or more nodes; B – moderately well sampled ecotypes, present at 3 or more nodes; C – rare ecotypes with small samples; D – common but under-sampled ecotypes; E – rare ecotypes, over-represented by targeted sampling; F – not sampled.

[3] The total number of plots in each ecotype (ecotypes as identified using field data, not by GIS analysis of the ecotype raster);

[4] The proportion of ARCN area covered by the ecotype, as mapped by Jorgenson et al. (2009).

[5] The area covered by the ecotype in ARCN (as mapped by Jorgenson et al. 2009) divided by the number of plots; this is a measure.

Table 1 (continued). Count of nodes, transects, and plots in ARCN ecotypes.

Ecotype[1]	Sample Adequacy Code[2]	Count of Nodes	Count of Transects	Count of Plots[3]	Area, % of ARCN[4]	Area per plot, km^2;[5]
Riverine Willow Low Shrub	C	1	1	5	0.17	30
Upland Alder-Willow Tall Shrub	D	2	3	7	5.11	634
Upland Birch Forest	C	2	2	2	0.37	160
Upland Birch-Ericaceous-Willow Low Shrub	A	10	17	45	11.78	227
Upland Dwarf Birch-Tussock Shrub	A	17	24	84	21.04	217
Upland Mafic Barrens	(E)	1	2	2	0.29	124
Upland Sandy Barrens	E	1	2	12	0.08	6
Upland & Lowland Sedge-Dryas Meadow	A	8	9	27	7.81	251
Upland Spruce-Birch Forest	C	2	2	3	0.41	118
Upland White Spruce Forest	A	4	5	18	5.82	280
Upland White Spruce-Lichen Woodland	E	1	1	7	0.08	10
Upland Willow Low Shrub	C	2	4	6	2.54	368

[1] Ecotypes are vegetation soil units mapped at 30-m pixel resolution in ARCN by Jorgenson et al. (2009).

[2] Assessment of sampling adequacy, see text for more explanation. A – well sampled ecotypes, with at least 18 plots at 5 or more nodes; B – moderately well sampled ecotypes, present at 3 or more nodes; C – rare ecotypes with small samples; D – common but under-sampled ecotypes; E – rare ecotypes, over-represented by targeted sampling; F – not sampled.

[3] The total number of plots in each ecotype (ecotypes as identified using field data, not by GIS analysis of the ecotype raster);

[4] The proportion of ARCN area covered by the ecotype, as mapped by Jorgenson et al. (2009).

[5] The area covered by the ecotype in ARCN (as mapped by Jorgenson et al. 2009) divided by the number of plots; this is a measure of sampling intensity: a large area indicates sparse sampling. The average for all of ARCN is 187 km^2/plot.

For change detection, the difference in the measure of interest (e.g., percent cover by some group of plants) between two dates is computed for each plot, and a single-sample t-test is used to test whether the resulting change value is significantly different from zero. The t-test function of the "survey" R package is used for this purpose, in order to account for the effects of post-stratum (ecotype) weights and clustering. The change analysis will typically be performed for a subset of strata (ecotypes), e.g. the upland and alpine tundra ecotypes. If network-wide inference is desired, then the ecotypes would be those with adequate samples (i.e. labeled A and B in Table 1).

The 471 plots on 78 transects distributed across ARCN should provide a sample large enough to detect many types of change, though a power analysis for change detection can only be approximated here, because of many possible values for the variance in the amount of change between dates, and the effect of clusters (sample plots clustered on transects). As a result of the cluster effect, the effective sample size in our change analysis will fall somewhere in between the number of plots and the number of transects available (see Table 1 for counts of both for the ecotypes). If the cover or basal area of a plant species were to increase by an average amount *x* across all plots in the subset of ecotypes tested, and if the standard deviation of these changes were also equal to *x* (i.e., a coefficient of variation of 1), a power analysis applying the one-sided, paired t-test with significance level of 0.05 indicates a required minimum effective sample size of 8 to obtain a power of 0.8. If the coefficient of variation were half the mean change, then n = 4 would suffice, while with a coefficient of variation of twice the mean change, n = 26 would be required (R statistical test "power.t.test"; R Core Team 2014). These are all plausible variance scenarios for future vegetation change, assuming that the variability of change will resemble the variability in current plant cover. Based on our first round of sampling, the majority (450 out of 594) of species-ecotype combinations where the cover by the species averaged at least 1% had coefficients of variation of less than 2.

A non-probabilistic sampling scheme such as ours remains vulnerable to charges of selection bias, even after correction with post-stratification weighting as outlined above. However, a statistically strong trend in the vegetation node data set, particularly if bolstered by a similar result from other ARCN monitoring by remote sensing from a systematically chosen ARCN-wide sample population (e.g., Swanson 2010, 2013), would provide good evidence for environmental change.

Models based on airborne laser data (LIDAR) and calibrated by plot data have been used successfully to predict forest biomass in un-sampled areas (e.g., McRoberts et al. 2014, Andersen et al. 2011). Similar GIS-based models may be used in the future to interpolate between the vegetation node plots, if suitable remote sensing data become available. Model-based inference based on geostatistics (Ver Hoef 2002) is also a promising option for ARCN-wide inference, if the analytical expertise is available. The multivariate analytical methods described in section 3.4 below may also be useful for understanding the vegetation node data.

2.5. Personnel requirements and training

In the first cycle node sampling was performed by a crew of 3 people consisting of a botanist/crew leader, botanist, and soil scientist. Two people work on point-intercept sampling, one as the observer and one as data recorder. Initial sampling with soil descriptions required one person trained to do a standard USDA soil description (Soil Survey Division Staff 1993); this qualification will not be required at re-samplings. While a crew of two could perform re-samplings, a crew of three is safer and more efficient in plot setup, and in forested environments the third person can complete tree measurements while the other two do point-intercept sampling. At non-forest plots the third person can collect plant unknowns and verify site characteristics, but will probably not be fully occupied with work.

The PI is a NPS permanent or term employee (GS-9, -11, or -12) responsible for planning and organizing field logistics, field sampling, and post-season database management. The PI provides training on the sampling routine and, as necessary, plant identification. The crew leader may be the principle investigator (PI,) or a GS-9 term-appointment employee with winter furlough, or temporary employee, under the supervision of the PI. The two field assistants who work the full field season are typically NPS seasonal employees (usually GS-5 to GS-7 Biological Technicians). An efficient system used in the first sampling cycle was for the PI to accompany a crew of three (including a crew leader) in the field for the first one or two nodes to provide training and quality control; the PI would then leave this crew and they would complete 5 or 6 nodes total in the season. The PI then joined with two other workers to form a second crew to complete an additional 2 or 3 nodes. These short-term field workers can be permanent NPS staff, short-term hires, volunteers, or seasonal hires who work also on other projects.

All crew members need to complete routine safety training common to all NPS field employees (bear safety and shotgun certification, basic aviation safety, first aid, CPR, and safety check-in procedures of the NPS units involved). One crew member should also be qualified as a special use fixed-wing flight manager (IATS 2014). Two people on the crew should have basic vascular botany skills; at least one person should have good familiarity with the flora of arctic Alaska, and at least one person should have knowledge of nonvascular botany sufficient to identify major species and genera.

2.6. Operational requirements

All sampling in the first round was between 1 July and 20 August. The ideal range would be narrower by about 5 days on both ends, as the early dates risk less than full leaf-out of herbaceous plants, while some leaf drop due to senescence occurs after August 15. As discussed above, each node requires about 5 days to sample. The 5-day period is followed by a location change, resupply of consumable items such as batteries and food, and a day off. Thus an average of 5 or 6 nodes can be sampled by one crew over a full field season, and 24 nodes can be sampled in 5 crew-years. However, the arrangement described above where the PI forms a second crew after training the first is preferred, because it would allow the full node set to be sampled in 3 years; this reduces the number of years where crew hiring and training must be completed, and also simplifies data analysis because sampling is more nearly simultaneous at all nodes.

Nodes are located within ½ to 1 ½ hours of flight time from staging areas of Bettles, Dahl Creek (near Kobuk), and Kotzebue. Two trips are required to transport the crew and gear (or one load if a DHC-2 “Beaver” aircraft is available). With hourly flight rates of $650 to $800, the seasonal charter cost for 5 nodes is $15,000 to $20,000. If NPS fleet aircraft are available, the cost is approximately half of commercial charters.

The NPS principle investigator works on budget and planning of the project occasionally throughout the year and about a month in midwinter planning fieldwork in advance of NPS compliance deadlines in mid-March. The PI accompanies the crew to the first one or two nodes, training and providing quality control. The seasonal employees typically start work mid-June for orientation and safety training. If the PI acts as a leader of a 2nd crew, (s)he will spend the rest of the time until mid-August in the field. The crew leader and 2 field assistants are in the field continuously from about 5 July to 15 August, with time off in Kotzebue, Bettles, or in camp. Field data are recorded primarily on field computers, so little post-season data entry is required, but a week or two of data checking and database management after the field season by the crew leader or PI is needed.

One to three hundred unknown vascular plant specimens requiring identification are expected to be collected annually. These may be identified by a seasonal employee, the crew leader, or by contract with the University of Alaska. A subset of these plants will be mounted for permanent collection, typically by staff at the University of Alaska Herbarium where the specimens will be stored. We use a limited list of non-vascular plants that the crew is trained on before the season, so we have not required nonvascular plant identification in the post-season.

3. ARCN-wide Lichen Community Composition Sampling

3.1. Background

The lichen composition sampling involves re-visits to plots established as a part of ARCN lichen inventories completed in 2004-2007 across the four western parks, and in 2012 in GAAR. These plots were sampled according to a modification of an established national monitoring protocol (USFS 2011). The modifications were made with the active participation of the authors of the original protocol and are described in section 3.3 below.

3.2. Plot location

In BELA, CAKR, KOVA, and NOAT, plots were located by a probabilistic design and accessed primarily by helicopter (Table 2). Plot locations are in the project database stored at https://irma.nps.gov/App/Reference/Profile/2166259/. Stratification was first by administrative unit and then by land cover type taken from classified satellite imagery. The BELA and NOAT park units were subdivided before cover-type stratification. NOAT was split along rivers into 4 roughly equal parts, while BELA was split using an 8 by 8 km grid, with grid squares aggregated to produce blocks approximately 400 km^2 (Fig. 2).

Table 2. ARCN lichen composition plots by geographic area.

NPS unit	Area, ha	Number of Plots	Area per plot, ha	Year(s) of 1st sampling
BELA	1,127,489	78	14,455	2000-2004
CAKR	267,202	29	9,214	2007
GAAR	3,430,054	79	43418	2012
KOVA	709,228	38	18,664	2007
NOAT (all)	2,655,854	89	29,841	2004-2005
NOAT, NE	718,557	17	42,268	
NOAT, NW	729,541	29	25,157	
NOAT, SW	566,304	25	22,652	
NOAT, SE	641,452	18	35,636	

Within these administrative-geographic blocks, actual plots locations were chosen by placing random points within strata based on land cover maps (Markon and Wesser 1998 for BELA, KOVA, and NOAT; Jorgenson et al. 2009 for CAKR). Lithologic and physiographic features derived from the ecological subsections mapping (Swanson 2001b) were also used in KOVA.

Due to the concern for cost and wilderness values in GAAR, lichen plots were clustered in 9 areas accessible by airplane (Fig. 2). The access points were buffered by a reasonable walking distance and random points chosen within land cover strata based on Jorgenson et al. (2009). An average of 9 plots were sampled from each access point, depending on the number of cover types available. This allowed 4 to 6 days of sampling from each access point, separated by air shuttles. A total of 79 plots were established in GAAR. The access points were well distributed across GAAR in an attempt to acquire a representative sample of each land cover type, similar to what would have been obtained from a completely randomized design as in the other park units.

Details of the procedure used to select plots are provided in Appendix A and Holt and Neitlich (2010a).

3.3. Plot layout and sampling

Plot design is a variant of the national FIA lichen sampling protocol (USFS 2011) adapted to arctic conditions. The FIA lichen protocol has been used successfully for change detection (Will-Wolf 2010). Under this protocol the sampler searches a fixed-area plot for macrolichens for a maximum of two hours, or until 10 minutes elapse with no additional species recorded, with a minimum time of at least 45 minutes per plot. The plot is 0.379 ha in size (34.7 m radius), the same area as the FIA lichen plot, but a simple circle without the excluded areas of the FIA plot and thus slightly smaller radius. Lichens are assigned an abundance class; the abundance scale was modified from the FIA protocol (designed for environments with mainly epiphytic lichens) to accommodate the dominant ground-dwelling lichens of arctic environments: 1 = rare (<3 thalli), 2 = uncommon (4-10 thalli), 3 = common (>10 thalli and <1% cover), 4 = abundant (1-5% cover), 5 = prolific (6-25% cover) and 6 = dominant (>26% cover). Because lichens often require chemical tests or microscopic examination to identify, many specimens are collected from most plots. Collections may be made from on the plot to save time, since the large plot size makes impacts negligible in most cases.

3.4. Data management, analysis, and reporting

Data from the first sampling event are described in Holt and Neitlich (2010b) and Nelson (2014).

The large plots and semi-quantitative abundance measurements of the lichen protocol lend themselves best to multivariate statistical analysis (McCune et al. 2002). These methods exploit the redundancy in information supplied by multiple species on a plot, allowing useful conclusions to be drawn about the status of the community, in spite of between-observer differences in species capture rates and abundance estimates (McCune et al. 1997). Ordination (e.g., Geiser and Neitlich 2007) or weighted averaging (e.g., Holt et al. 2006) are used to develop a scoring system for plots along a gradient such as air pollution or grazing intensity. This analysis produces a weighting value for each species, and the abundance value for each species found on a plot can be multiplied by the weight and averaged over the plot to obtain a score for the plot. These gradient scores can be analyzed for change over time, as well as their relationship to environmental factors. One particularly useful analysis is to use a predictive mode of ordination ("NMS Scores" in PC-ORD software, McCune et al. 2002) to score repeat measurements based on an ordination of the original plot measurements. Multivariate Analysis of Variance (MANOVA, Anderson 2001) is useful for testing differences between groups. Villareal et al. (2012) successfully applied NMS ordination and MANOVA to track long-term changes in vegetation plots in a wet tundra environment, similar to parts of ARCN, near Barrow, Alaska.

Inasmuch as the plot locations in were chosen by probabilistic design, ARCN-wide inference is possible from analysis of the lichen community plots, with the caveat that some parts of the network were excluded from the sampling frame as described in Appendix A. Notably, certain cover types were excluded from sampling e.g., in BELA no plots were placed in the lichen-poor cover types such as “wet herbaceous”; and in GAAR only areas near access points were included. Model-based inference may be helpful to extrapolate the GAAR data across un-sampled portions of the park. However, this more complex analysis may not be necessary, as inferences based our spatially-limited but well dispersed sample could reasonably be extended across the un-sampled parts of the park, if corrections for clustering of samples and weighting of strata are performed as described above in section 2.4 for the vegetation nodes.

3.5. Personnel requirements and training

Three key personnel are involved in these lichen composition monitoring projects: an NPS contact, a project leader, and one or two field assistants.

The NPS contact is the contact for an agreement or contract, or the supervisor of a project leader if this is an NPS term position. (S)he is responsible for organizing the contract, agreement, or term position, organizing the safety training, organizing field logistics, and providing the orientation training on project goals, logistics, and sampling methods.

The field crew consists of two or three people: a project leader and one or two field assistants. The project leader could be as an NPS term position (GS-9 or GS-11 level), a contract employee, or a graduate student or assistant working under a cooperative agreement with a university. The field assistants are typically seasonal employees or volunteers employed by NPS or the university cooperator.

Major functions to be performed by the project leader and assistant are 1) plot location and sampling setup, photography, and recording of environmental variables (slope, aspect, etc.); 2) field lichen identification and collection; 3) laboratory lichen identification; and 4) data analysis and reporting. The lichen identification functions require a high level of expertise in lichen taxonomy, typically obtained through post-graduate education at an institution with faculty specializing in lichen research. Data analysis requires familiarity with traditional and multivariate statistics. The most likely staffing scenario is for the project leader to perform functions 2, 3, and 4, while the field assistants are present for safety and function 1. An alternate scenario involves a field assistant who is a lichen taxonomy expert and performs functions 2 and 3, while the project leader performs 1 and 4.

In addition to prerequisite basic training on lichen identification that would be obtained prior to hiring or contracting, the person responsible for field lichen identification will require specific orientation to ARCN’s lichen communities if (s)he does not have prior experience in this or similar environments. This orientation may be provided by NPS staff or outside experts and completed in about a week in the field prior to the first field season. In the absence of this orientation, a highly qualified lichen expert may accomplish orientation independently during a period of a week or two prior to the first field season.

The field crew will also need to complete routine safety training common to all NPS seasonal employees (bear safety and shotgun certification, basic aviation safety, first aid, CPR, and safety check-in procedures of the NPS units involved). This training is typically available at one of the NPS offices over several days at the start of field season. Specialized helicopter safety training (helicopter crew member training followed by helicopter manager training) will be required for the project lead, the field assistant, or another person present for projects requiring helicopter use. This training currently requires approximately 1 week for each course and may require travel to complete.

3.6. Operational requirements

In all of the ARCN NPS units except GAAR, the lichen composition plots are accessed by helicopter with about 2 hours spent on the ground at each plot and about 3 plots per day sampled. Because of the relatively short time at each plot and the need to move several times during the day, a helicopter will usually be devoted specifically to this project. Sampling may take place any time in the snow-free season, typically from early June to early September. At 2010 contract prices a helicopter costs roughly $3,500 per day, including fuel and fuel logistics. With 230 helicopter-access plots to be sampled at an average of 3 per day, this amounts to about 75 days of helicopter charter. Thus aviation costs will be the main limitation on re-sampling plots, and re-sampling will be probably conducted under project-specific funding for only part of the network at a time. A statistically-based subset of lichen plots could be identified for future sampling in order to reduce costs and logistics (Holt and Neitlich 2010a).

In GAAR the lichen composition plots were clustered in groups of 8 to 10 plots near a lake or air strip that can be accessed by fixed wing aircraft from Bettles. The plots can be reached on foot and sampled at a rate of 2 or 3 per day, resulting in about 4 to 6 days per location followed by a day spent shuttling to the next air access point. After 2 or 3 locations (about 2 weeks) the crew can fly back to Bettles for resupply and time off. The field season consists of 3 or 4 such stints of 2 weeks in the field to sample the total set of 79 plots. There are approximately 10 air shuttles (to and from Bettles and between sites) that each require 2 to 5 hours of air time at $600 to $800 per hour, depending on the aircraft and location, for a seasonal transportation bill of $25,000-$30,000. Additional costs include air fare from the employees’ duty stations to Bettles, and per diem.

Lichen sampling is collection-intensive, and a full sampling season will typically be followed by a 6-month period of full-time work on identification and data analysis by the project leader. Lichen identification requires laboratory facilities (microscopes, chemical reagents, and reference books) that must be kept up to date if the work is performed by NPS employees. Part of the field data will be collected on field computers, and post-season data entry demands will be small relative to the lichen identification and statistical work.

4. Red Dog Mine Haul Road Monitoring

4.1. Background

One of the largest zinc and lead mine in the world, Red Dog Mine, is located approximately 50 km northeast of the boundary of CAKR and 10 km from the boundary of Noatak National Preserve. The mine has operated year round since 1989 to produce zinc (Zn) and lead (Pb) concentrates (approximately 50-55%) in fine powder form. Concentrates are hauled approximately 75 km in covered trucks via the DMTS (referred to here as the Red Dog Mine haul road) from the mine site to the concentrate storage buildings at the Red Dog Port Site on the Chukchi Sea. The concentrates are then conveyed to barges for shipping during the short ice-free shipping season each summer.

The Red Dog Mine haul road traverses approximately 32 km of CAKR. Eighty ton concentrate haul trucks and other vehicular traffic have been dispersing fugitive dusts onto NPS lands since 1989. These dusts are enriched with Pb, Zn, Cd, and S, all in reduced sulfide forms (Exponent 2007). Metal-laden muds and dusts originate in the mine pit, waste rock areas, and concentrate loading and unloading facilities. Once attached to vehicles, they become dispersed onto the roadbed and surrounding tundra on the 75 km trips to and from the mine and port sites.

From 1991-2000, concentrate haul trucks were covered only with tarps. In 2001, a new fleet of trucks was purchased with sealed lids, and in 2003 procedural modifications were incorporated at the port facility to reduce concentrate dust losses during unloading and loading operations (Exponent 2007). Truck washing was also installed for the four months of the year with above-freezing temperatures, which helped reduce fugitive dust dispersal during those months.

Beginning in 1999, researchers began to use the moss *Hylocomium splendens* to document patterns of airborne heavy metal deposition on NPS lands from mining operations at Red Dog Mine. In 2001, Ford and Hasselbach reported elevated concentrations of cadmium (Cd >10 ppm) and Pb (> 400 ppm) in *H. splendens* moss along the haul road corridor. In 2005 Hasselbach et al. documented strong gradients in Pb, Cd and Zn deposition in CAKR related to the DMTS, the Port Site and the Mine Site. Heavy metal levels in moss were highest immediately adjacent to the haul road (Cd > 24 ppm; Pb > 900 ppm).

Analysis of subsurface soil suggested that observed patterns of heavy metal deposition reflected in moss were not attributable to subsurface soils in the study area (Hasselbach et al. 2005). Further, Pb concentrations in moss throughout the northern half of the study area were higher than background concentrations previously reported from other Arctic Alaska sites. Collectively, these findings indicate the presence of mine-related heavy metal deposition throughout the northern portion of CAKR.

Both Zn and S are powerful lichen toxins. Dozens of lichenological studies have demonstrated injury and mortality of lichens in the presence of Zn, sulfate and sulfides from both industrial point sources (e.g., smelters, mines) and regional plumes (e.g., Folkesson and Andersson-Bringmark1988, Nash 1975).

In response to the potential threat posed by contaminants in dust along the Red Dog Mine haul road, a series of plots was established in 2006 to determine the degree of degradation to plant communities. That study determined that significant adverse effects on vegetation had already occurred; the present protocol is designed to formalize repeat sampling of these plots to track recovery or continued degradation in the future.

4.2. Plot location

Hasselbach et al. (2005) found that deposition of heavy metals decreased logarithmically as a function of distance from the DMTS road. To approach the question of vegetation change as a function of contaminant level, we used a stratified-random design based on two dominant landcover classes, establishing permanent plots based on distance classes from the road. The sampling design was intended to reflect this log-based decay function while also controlling for natural differences in vegetation community types and elevation.

The most common vegetation types along the road are Upland Moist Dwarf Birch-Ericaceous Shrub and Upland Moist Dwarf Birch-Tussock Shrub (Jorgenson et al. 2009). Together, these closely related classes account for 66% of the area along the road corridor out to 4000 m distance. Both of these community types are fairly rich in the nonvascular plants that were known to be sensitive to Zn and S contaminants as well as alumino-silicate road dust. The two community types are very similar compositionally; the main difference between them is that the latter has greater than 15% cottongrass (*Eriophorum vaginatum* L.) cover while the former is co-dominated by dwarf birch (*Betula nana* L.) and ericaceous shrubs.

In order to maximize the signal from contaminants and to minimize the noise from natural variation in community structure across different vegetation types, we limited our sampling to these two most common community types. To avoid confounding the pollution signal with natural vegetation variation due to elevation and hydrology, we avoided sampling in any alpine communities and restricted our sampling to between 61 and 244 m (200 and 800 ft) elevation. Sampling distances from the road were established in an attempt to obtain an even spread of values along the Zn deposition gradient in the conditional simulation models reported by Hasselbach et al. (2005). Twelve "transects" were created according to the distances in Table 3, with points at the following distances from the road (in m): 10, 50, 100, 300, 1000, 2000, and 4000. One autocorrelation plot was established in each transect at a random distance 10 to 20 m from the 1000, 2000, or 4000m plot in each transect. Each "transect" consisted of a group of points at specified distance classes and landcover classes chosen at random in ArcGIS 9.2 in close geographic proximity, rather than a linear feature, per se. Linear transects were first attempted in the planning phase, but rejected as it was impossible to find both the correct landcover classes and distances along a straight line.

Two sets of reference plots were also established as follows: Two general reference areas were chosen at random from points in CAKR with sufficient representation of the two desired landcover classes, and at a distance of at least 20 km from the DMTS. Each reference area had 3 replicates of each landcover class, making for a total of 12 pre-chosen reference plots. Only 10 of these were completed during the initial round of sampling (Table 3).

Table 3. Number of monitoring plots by distance from the Red Dog Mine haul road.

Distance from Road, (m)	Plot Type	N	Mean Modeled 2001 Zn (mg/kg[1])
10	Standard	12	1351
50	Standard	12	1192
100	Standard	12	990
300	Standard	12	591
1000	Standard	12	227
1000	Autocorrelation	8	227
2000	Standard	11	156
2000	Autocorrelation	1	156
4000	Standard	11	112
4000	Autocorrelation	3	112
42,000 – 48,000	Reference 1	4	43
60,000	Reference 2	6	40

[1] Modeled 2001 Zn concentration levels in moss were obtained from data derived from Hasselbach et al. (2005).

4.3. Plot Layout and Sampling

Plots are a 4 m by 8 m rectangle oriented parallel to the road (Fig. 10). Plot locations were recorded using differentially corrected GPS and marked with a rebar spike on one corner as specified in the database. Point intercept measurements are made at 100 points using a laser pointer on a staff. Points are arrayed in a regular grid consisting of 10 lines oriented perpendicular to the long axis of the plot at 80 cm intervals; each line has 10 points separated by 40 cm.

At each point, the plant species or other substrate (e.g., mineral soil, duff, water, litter) touched by a vertical beam from a laser mounted on a staff is recorded. If multiple strata of live plants occur along the laser beam, each is recorded. The plot is additionally surveyed for taxa not detected in the point counts. Macrolichens and vascular plants are either assigned a species name in the field or vouchered (off plot if possible) for later identification. Some lichen chemo-species (differentiated only by chemical tests) are grouped. Bryophytes are not recorded to species, but rather to five morphological groups: *Sphagnum* spp., *Hylocomium splendens,* acrocarpous mosses, pleurocarpous mosses (other than *Hylocomium*), and liverworts. Acrocarpous mosses are sparingly branched with sporophytes at branch tips (common genera in ARCN are *Auloconmium, Dicranum* and *Polytrichum*), while pleurocarpous mosses are highly branched and have sporophytes on short side branches (e.g. *Hylocomium*, *Drepanocladus*, and *Pleurozium*).

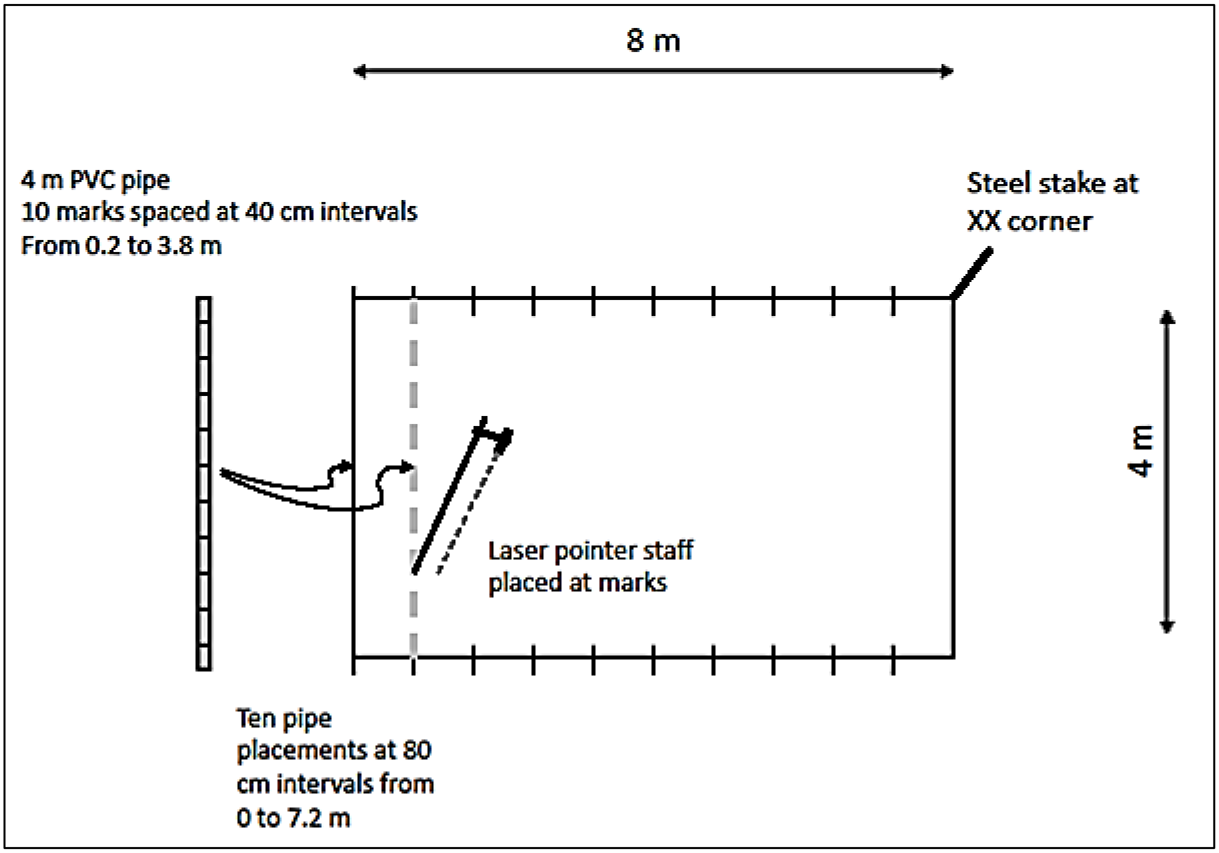

Figure 10. Layout of 4 X 8 m lichen sample plot.

4.4. Data management, analysis, and reporting

Data from the first instance of this sampling (2006) are currently being analyzed in relation to the gradient of distance from the road. Lichen species richness and total cover showed strong correlations with log-transformed distance from the road. Ordination of lichen communities also showed a strong relationship between community composition and distance from the road. Data from the first instance are available from Holt and Neitlich (2010b).

In the future, both distance from the road and time will be tested for effects on lichen communities. After two or more sampling instances, analysis of covariance will be used to test for differences in species richness between the dates, with log-transformed distance from the road as a covariate. The same analysis will be performed for total lichen cover and cover of selected species or species groups, such as caribou forage lichens. We are interested in testing for changes through time in both the slope and intercept of the relationship between lichen diversity (or cover) and distance from the road (Fig. 11)

Species cover data will also be analyzed with ordination by Nonmetric Multidimensional Scaling (McCune et al. 2002). Ordination of the 2006 data by Neitlich et al. (in preparation) produced a major axis that corresponds to the gradient of distance from the road (i.e., the rate of metal deposition). Ordination of data from 2 or more dates are likely to produce a similar axis. If the ordination scores on this axis for the plots change significantly between dates, this would imply a change through time analogous to the change in space seen as one moves closer or farther from the road. In other words, it would suggest a change in the width of the zone of degradation. If change between dates is significant for the ordination scores of plots along another axis, orthogonal to the one corresponding to distance from the road, it would suggest that some other kind of trend with time is occurring. Also, plot re-measurements may also be score-fitted to the original 2006 ordination to track the movement of plots or zones of degradation along the original pollution gradient with ordination scores (McCune et al. 2002).

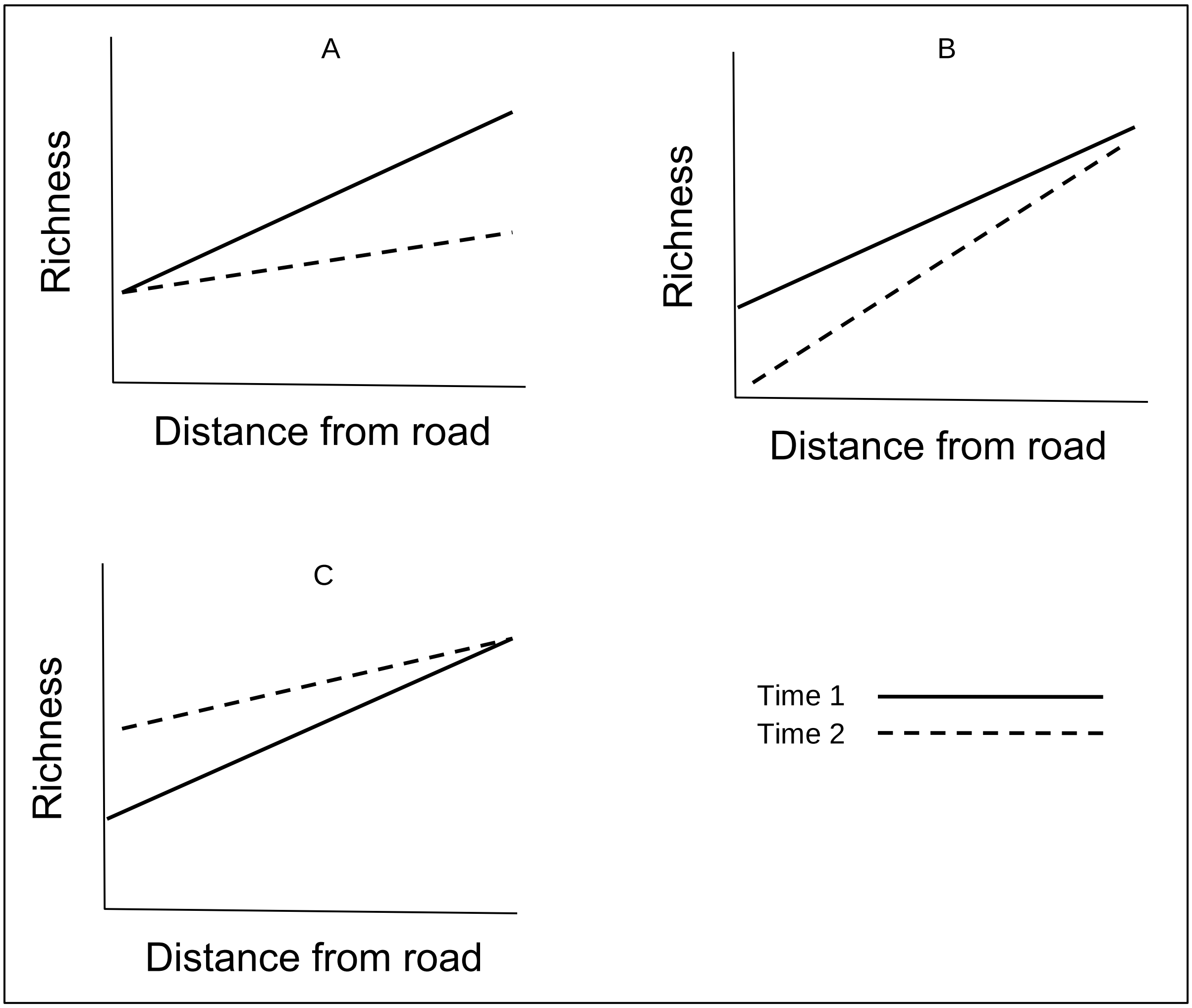

Figure 11. Potential scenarios for change in species richness through time in relation to distance from the road. A –widening of the zone of impact; B – continued loss of species near the road; C – recovery.

4.5. Personnel requirements and training

This project requires an NPS contact and field crew of three people: a field leader and lichenologist, a second skilled lichenologist, and a general field technician. The role of the NPS contact is similar to that described in section 3.5 above and the basic safety and aviation training required of crew members is also the same. The field crew will require a high level of expertise in lichen taxonomy as described in section 3.5. In view of the tedium involved with prolonged point-intercept sampling, the field crew should contain two people with a high level of lichen identification expertise who can alternate roles as point-intercept sampler and data recorder. The technician can do plot setup, record GPS coordinates, record lichen and environmental data, and collect samples of *Hylocomium* moss for tissue analysis. (The *Hylocomium* moss collection and analysis procedure is covered under the ARCN “Wet and Dry Deposition” monitoring vital sign.) Safety and project orientation training needs are similar to the previous project (section 3.5).

4.6. Operational requirements

The Red Dog Mine haul road is accessed by charter aircraft from Kotzebue to the mine site and a vehicle along the road for most of the plots (n = 84). In the past, the mine operator, Teck, Inc., has provided NPS with a vehicle to use for several weeks during the sampling. NPS also has a very old military pickup truck that may be used if needed. The 12 plots at 4000 m from the haul road and ten reference plots (located 42 to 60 km from the road) require helicopter access. If funding is extremely tight, the reference sites could be omitted without consequence, as they are not in the final ordination model. The plots 4000 m from the road could also be accessed on foot, but it would take an additional 3-4 hours per plot to accomplish this due to the long distances over tussock tundra terrain. Alternately, a helicopter could be procured for 2 days of work to complete the 4000 m plots. Lodging in the past has been at either the port site or the mine site, though at times a construction camp is also available. Camping at a materials site (i.e., gravel pit) accessible from the road is also an option. Plots can be completed at a rate of 5 or 6 per day for a total of approximately 20 days for the entire project. Without helicopter support for the 4000 m plots, approximately 26 days would be needed.

Some of the personnel and transportation may be shared between the lichen plot sampling and the sampling of *Hylocomium splendens* moss for contaminants as a part of the ARCN vital sign “Wet and Dry Deposition” (Hasselbach et al. 2005). The *Hylocomium* study involves 151 moss collection plots, about half of which are accessible on foot from the Red Dog haul road and half by helicopter. These plots require about 10 days to sample, about 4 of which require helicopter. If done concurrently with the Red Dog Mine haul road lichen monitoring plots, the time required would be approximately halved.

Lichen collections must be processed after the field season as described in section 3.6.

5. BELA Ungulate Grazing Exclosures

5.1. Background

The entirety of BELA's 2.8 million acres has been allocated to reindeer grazing in five main grazing allotments. BELA's enabling legislation provides for long-term reindeer grazing according to sound range management practices that do not degrade preserve resources (ANILCA 1980). NPS issues permits for reindeer grazing to four allotment holders on a regular basis for a maximum number of animals on each range, typically 1000-2000. NPS is responsible for developing a grazing management plan in which permitted numbers of animals are based on the desired condition of the resource, according to the best available science. This task is complicated by the fact that caribou, which have essentially the same dietary needs as reindeer, have increasingly occupied BELA as winter range and in small numbers as summer range (Dau 2005), and NPS is also charged with protection of wildlife habitat by ANILCA (1980). The combined effects of reindeer and caribou grazing have reduced lichen cover in BELA, with locally severe impacts (Holt et al. 2008). Loss of lichens has been noted throughout the western arctic caribou herd winter range, and is apparently due to the combined effects of grazing, fires, and climate change (Joly et al. 2006, 2009).

Analysis of lichen community composition plots in BELA (see part 3 above and Holt et al. 2008) indicates that the only way to establish the condition of BELA's winter range definitively is to characterize it relative to the grazing endpoints of "highly degraded" and "ungrazed". While we have found examples of severe damage due to overgrazing in BELA, the only way to characterize an "ungrazed" winter range over the long term is to exclude animals from grazing. Furthermore, given complex effects of herbivores, fire, and climate change on lichens, exclosures are the only sure way to isolate the effect of grazing from other factors. To illustrate this point, consider the differing grazing management decisions that might be made in response to a widespread decline in lichens across the Preserve. If lichen communities inside exclosures showed a similar decline, we would probably conclude that grazing pressure at current levels is not contributing to the decline; in contrast, if communities inside exclosures show steady or increasing lichen biomass while the biomass outside declined, we would conclude that grazing is the cause of decline outside.

A number of prior attempts at establishing exclosures have been made on the Seward Peninsula. Unfortunately, these have not been maintained well enough to provide a long-term record of vegetation change. The older exclosures were erected using wooden posts dug into permafrost, and the posts were ultimately ejected and structures were ruined. The current proposal uses a freestanding design that is not permanently anchored into the ground: each exclosure will be constructed out of twelve 6 ft x 10 ft chain link fencing panel, with panels clamped together to form a large 30 ft x 30 ft square (Fig. 4). The exclosure should be unaffected by frost heaving and is designed to last 30-50 years. The exclosures are intended for use as grazing reference areas for multiple decades, but they could be removed at any time with almost no trace.

5.2. Exclosure locations

Eighteen exclosures were constructed in BELA in 2012, 3 replicates in each of 5 land cover classes (Table 4, Fig. 12). We targeted 5 primary landcover classes that differ in elevation, rockiness, lithology, and lichen community type. We also targeted one special area near Kuzitrin Lake that has received very heavy grazing, as this represents a damage class endpoint in BELA. The exclosures and associated “open” (unfenced) plots are not in themselves intended to be used for design-based inference about the range condition of the Preserve as a whole, but rather as a representative sample for creating a rating system for our existing lichen community composition plots, which can be used for Preserve-wide inference. The exclosure sites were selected from our lichen community composition plots, which were originally located by objective design, as described in section 3. The subset of plots was chosen for exclosures by the following criteria: a) the desired landcover strata (Table 4), b) at least 15% lichen cover, c) a slope of 5 degrees or less, d) enough homogenous land cover to provide for analogous adjacent plots inside and outside the exclosure, and d) flat enough to permit the exclosure to stand strong for 30-50 years. From within the starting population of all of the lichen community composition plots, there were only approximately 25 that met all the criteria; several others were borderline. In the end, this made our choice of plots more obligatory than subjective. This selection of plots representing the range of typical conditions in potentially lichen-rich communities across the preserve is the most efficient way to obtain a meaningful result from a necessarily rather small sample.

Table 4. Exclosure locations by landcover class (Jorgenson 2009)

Landcover Class	Number of Exclosures
Upland Moist Dwarf Birch Tussock and Ericaceous Shrub Tundras	3
Upland Moist Sedge-Dryas Meadow	3
Alpine Alkaline Dry Dryas Shrub and Barrens	3
Alpine Nonalkaline Dry Dryas Shrub and Barrens	3
Upland Dry Lichen Barrens	3
Kuzitrin Lake Intensive Recovery Sites (on Landcover Types above)	3

5.3. Plot layout and sampling

The data at each site consists of vegetation community surveys using 100 point counts on four 4 x 8 m plots identical to those used in the Red Dog Mine haul road study (section 4). Two of these plots are inside the exclosure. Two other plots are outside and adjacent to the exclosure, and in most cases, inside the larger long-term lichen composition monitoring plot (section 3). Each vascular plant and lichen is identified to species level; bryophytes are classed into functional groups (*Sphagnum* spp., acrocarpous moss, pleurocarpous moss, *Hylocomium splendens*, liverwort). Lichen mat height is recorded for 7 dominant taxa and for the exclosure as a whole and converted to biomass via predictive equations developed from sampling in 2010 (Rosso et al. 2014). Site data includes physiographic variables, pH, and a suite of GIS-derived climate and landcover variables.

5.4. Data management, analysis, and reporting

Several types of data analysis are run on the exclosure plot data. Quantities that can be reduced to a single measure per plot (lichen species diversity, estimated lichen biomass, total lichen cover, and cover of selected species or species groups) will be subjected to analysis of variance and covariance.

The vegetation stratum (landcover class, Table 4) and exclosure status (plot inside or outside of the exclosure) are independent variables and time since exclosure construction is a covariate.

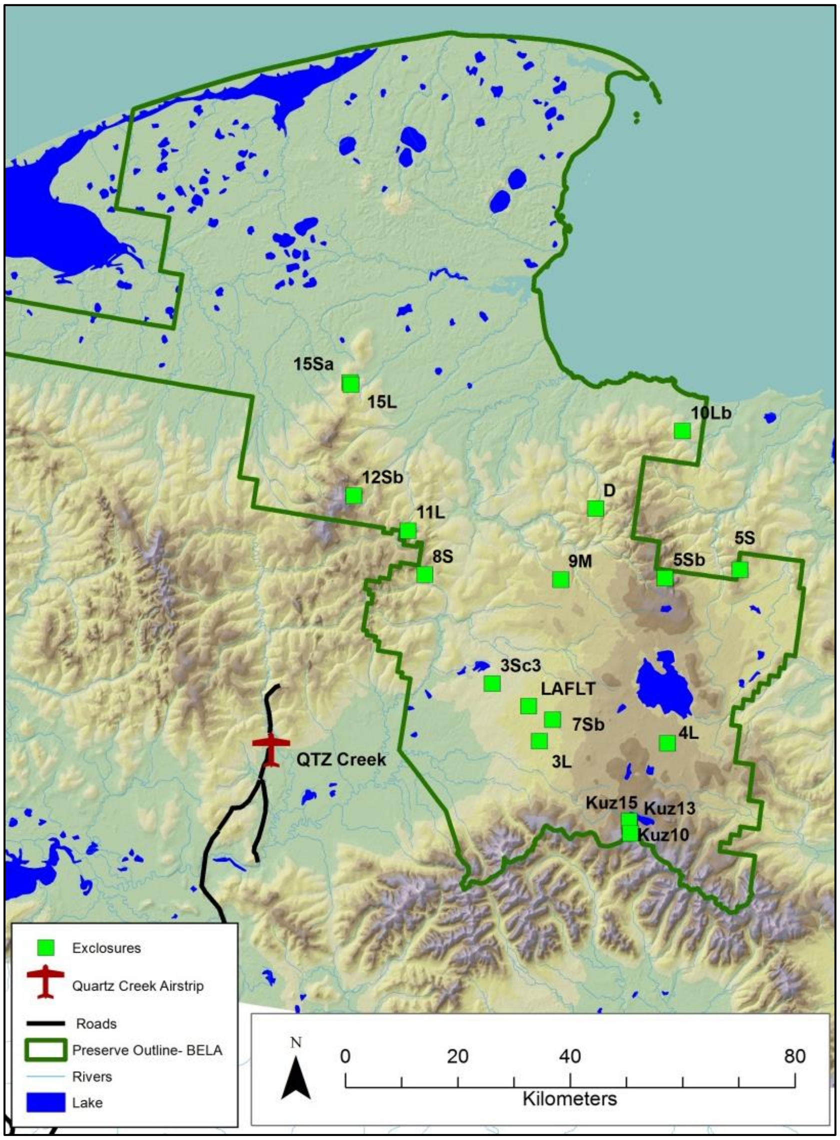

Figure 12. Locations of 18 grazing exclosures in BELA and the Quartz Creek landing strip on the road system that is used as a helicopter staging area.

Multivariate community analysis will also be performed. The species composition of communities inside the exclosures is expected to diverge over time from that of communities outside the exclosures. After several decades the plots inside exclosures should become useful as end members in a weighted averaging analysis (McCune et al. 2002) that will be used to score grazing impacts on unknown new plots. Also after several decades, ordination of the plots (by Nonmetric Multidimensional Scaling, McCune et al. 2002) may produce an axis that defines a gradient between impacted plots outside exclosures and unimpacted plots inside, and the ordination will be used to score grazing impacts on unknown new plots. Groups comparisons will also be made by Multiresponse permutation procedure (MRPP; McCune et al. 2002) to produce statistics on the degree of divergence between exclosed and unexclosed plots, and within subgroups of these (i.e., different landcover types, topographic positions, lithologies, grazing intensities).

5.5. Personnel requirements and training

Any new exclosure construction will require an exclosure crew consisting of two or three people who between them have a trained helicopter manager, experience in helicopter sling loading, knowledge of the fencing construction method to be used, and the ability to navigate to the selected site and choose the exact fencing and plot locations. One of these workers should be the NPS contact who selected the plot locations. The helicopter pilot must be AMD certified in sling loads and experienced in flying bulky loads. The plots inside and outside of a new exclosure should be sampled in the same summer as their construction.

Routine re-sampling of the plots requires a field crew of three people with the same qualifications as described for the Red Dog Mine haul road plots described in section 4.5 above.

5.6. Operational requirements

For any new exclosures, fencing materials and fuel can be staged from the road-accessible Quartz Creek landing strip, and fencing materials sling-loaded to the exclosure sites. The 10 ft by 6 ft fence panels may be slung in bundles of six with an R44 helicopter, requiring 2 trips per exclosure for fencing and a third trip for the fence-construction crew. Ferry distances range from about 35 to 100 km. An average round trip of 100-120 km will take about an hour if loads are ready, and between one and two exclosures can be constructed per day.

The sampling crew will require one or two trips per exclosure, depending on the size of crew and helicopter, and the crew can expect to complete one set of 4 plots at an exclosure per day. A single sampling crew spending all day at an exclosure would not be able to make efficient use of a helicopter, because less than 3 hours of flight time per day would be needed. If the personnel is available to compose two or three field crews, they would be able to use enough helicopter time per day to match the typical 4-hr minimum daily charges and complete all 18 exclosures in a week to 10 days. At the 2014 hourly rate of about $1000 for an R44 helicopter, about $30,000 would be required to transport crews to all 18 exclosures.

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Appendix A: ARCN-wide Lichen community monitoring plot location selection

BELA.

In BELA, the four land cover types (Markon and Wesser 1997) with highest cover (averaging over 10% lichen cover), as determined in a pilot study, were selected for sampling (Table A1). The Preserve was then divided into 21 blocks composed of 8 by 8 km grid squares aggregated to produce blocks approximately of 400 km^2 (section 3.2 and Fig. 2 above). Four points within each cover type were randomly selected within each geographic block, with the added condition that there must be 9 contiguous pixels of the cover type. The latter condition eliminated most misclassified pixels, but in some cases fieldwork revealed that the point was not in the target type, in which case the next point in that stratum was substituted. Plots were visited in the order they were originally chosen, and time constrained sampling to only one or two of each cover type per block.

Table A1. Cover type strata in BELA for lichen sampling[1]

Cover Type	Area Covered (%)
Closed Low Shrub - Alder/Willow	5.5
Closed Low Shrub - Dwarf Birch/Ericaceous	9.4
Open Low Shrub - Alder/Willow	2.6
Open Low Shrub - Dwarf Birch/Ericaceous	24.1
Dwarf Shrub - Lichen Dominated	6.2
Mesic/Dry Herbaceous	22.0
Wet Herbaceous	13.1
Sparse Vegetation	4.1
Barren	0.3
Clear Water	5.1
Silty Water	2.8
Shadow	0.0
Dwarf Shrub - Tussock Tundra	4.8

[1] Cover types in **boldface** average over 10% lichen cover in a pilot study. The land cover types were from a Landsat classification by Markon and Wesser (1997).

NOAT.

In NOAT, the 15 vegetated cover types present in the Preserve on a Landsat-derived cover type map (Markon and Wesser 1998) were aggregated based on similarity into 7 strata (Table A2). Sampling effort was allocated to the strata based on the rarity-weighted species richness of the strata, as computed from the first $1/5^{th}$ of plots sampled (McCune et al. 2009). Points were again chosen randomly with the added condition that only contiguous blocks of 9 pixels of the proper class were eligible for selection, and misclassified points were substituted as in BELA.

KOVA.

In KOVA, the original 14 land cover types present in the Park on Markon and Wesser (1998, the 5th column in Table A3) were aggregated based on similarity into 8 types (column 4). Some of these 8 aggregated types were then split based on lithology (carbonate lithologies versus non-carbonate, "acidic") or other landscape criteria (column 3) to produce the final 14 classes (column 1). Three random locations were selected in each of the 14 final strata, and again only clusters of 9 or more contiguous pixels were accepted. However, in this case misclassifications affected enough of the randomly chosen plots that 16 additional subjectively located plots of the proper cover type were chosen in the field and sampled, to bring the total to 38 plots.

CAKR.

In CAKR, the land cover stratification was based on a newer map by Jorgenson et al. (2009) that included carbonate substrate lithology as a class, making the layered stratification used in KOVA unnecessary (Table A4). Three points per stratum were randomly chosen, again with the condition of 9 contiguous pixels. One to three randomly chosen points were actually sampled per stratum, and in the case of Alpine Alkaline Dry Dryas Shrub, two plots were chosen deliberately to compensate for misclassifications.

Table A2. Cover type strata in NOAT for lichen sampling

Aggregated Land Cover	Count of Plots	Area Covered (%)	Original Land Cover
Alder-willow	12	18.0	Closed low shrub - alder/willow
			Open low shrub - alder/willow
			Tall open and closed alder/willow
Conifer forest	12	9.9	Closed needleleaf forest
			Needleleaf woodland
			Open needleleaf forest
Dwarf shrub	11	26.1	Dwarf shrub tundra/dwarf shrub peatland
			Open low and dwarf shrub tussock tundra
Herbaceous community	18	10.5	Moist or dry herbaceous
			Wet herbaceous
Low birch/Ericaceous	12	19.7	Closed low shrub - birch/ericaceous
			Open low shrub - birch/ericaceous
Sparse Vegetation	8	11.9	Barren
			Sparsely vegetated
Talus lichen	16	3.9	Open dwarf shrub - talus/lichen

Table A3. Cover type strata in KOVA for lichen sampling

Final Land Cover Stratum	Count of plots (Random, Nnonrandom)	Lithology and other criteria	Aggregated land cover	Original Land Cover
Alder/Willow	1, 2	(none)	Alder/Willow	Closed low shrub - alder/willow Open low shrub - alder/willow Tall open and closed alder/willow
Riparian Barrens and Willows	1, 1	Adjacent to Clear Water LC pixel	Barren/sparse	Barren
Sparse Vegetation Acidic	2, 1	Acidic		
Sparse Vegetation Carbonate	4, 0	Carbonate		Sparsely vegetated
Stabilized Sand Dunes	0, 2	Kobuk Sand Dunes Subsection		
Closed needleleaf forest	2, 4	(none)	Closed needleleaf forest	Closed needleleaf forest
Dwarf Shrub Acidic	0, 1	Acidic	Dwarf Shrub	Dwarf shrub tundra/dwarf shrub peatland
Dwarf Shrub Carbonate	2, 2	Carbonate		
Low Birch Ericaceous Acidic	3, 2	Acidic	Low Birch Ericaceous	Closed low shrub - birch/ericaceous Moist or dry herbaceous Open low shrub - birch/ericaceous
Open needleleaf forest	1, 0	(none)	Open needleleaf forest	Needleleaf woodland Open needleleaf forest
Talus Lichen Acidic	2, 0	Acidic	Talus Lichen	Open dwarf shrub - talus/lichen
Talus Lichen Carbonate	2, 1	Carbonate		
Tussock Tundra	2, 0	(none)	Tussock Tundra	Open low and dwarf shrub tussock tundra

Table A4. Land cover stratification of lichen plots in CAKR

Aggregated Land Cover	Count of plots (Random, Nnonrandom)	CAKR - Original Land Cover
Alpine Alkaline Dry Barrens	2	Alpine Alkaline Dry Barrens
Alpine Alkaline Dry Dryas Shrub	1, 2*	Alpine Alkaline Dry Dryas Shrub
Alpine Nonalkaline Dry Barrens	1	Alpine Nonalkaline Dry Barrens
Alpine Nonalkaline Dry Dryas Shrub	3	Alpine Nonalkaline Dry Dryas Shrub
Coastal Barrens and Meadow	2	Coastal Barrens
		Coastal Dry Dunegrass Meadow
		Coastal Wet Sedge-Grass Meadow
Dwarf Birch-Tussock Tundra	2	Lowland Wet Dwarf Birch-Ericaceous Shrub
		Upland Moist Dwarf Birch-Ericaceous Shrub
		Upland Moist Dwarf Birch-Tussock Shrub
Graminoid	2	Lowland Sedge Fen Meadow
		Lowland Sedge-Moss Fen Meadow
Lowland Willow	3	Lowland Moist Dwarf Birch-Willow Shrub
		Lowland Moist Low Willow Shrub
		Lowland Moist Tall Alder-Willow Shrub
Riverine Barrens and Willow	3	Riverine Barrens
		Riverine Moist Dwarf Birch-Willow Shrub
		Riverine Moist Low and Tall Willow Shrub
Sedge-Dryas Meadow	2	Lowland Moist Sedge-Dryas Meadow
		Upland Moist Sedge-Dryas Meadow
Upland Dry Crowberry Shrub	2	Upland Dry Crowberry Shrub
Upland Moist Low Willow Shrub	2	Upland Moist Low Willow Shrub
Upland Moist Spruce Forest	2	Upland Moist Spruce Forest
(not sampled)	0	Coastal Water
		Human-Modified Barrens
		Lacustrine Moist Bluejoint Meadow
		Lowland Water
		Riverine Water

*One randomly chosen plot and 2 plots placed deliberately in the cover type.

GAAR.

In GAAR, fixed-wing air access was used to reduce cost and protect park wilderness values. Nine lakes were chosen that provided safe floatplane landing/takeoffs, foot access to a variety of terrain types, and broad distribution across the park. The ecotype map of Jorgenson et al. (2009) was used to stratify the vicinity around each landing lake and select plot locations. Ecotypes were first aggregated into 9 similar types as shown in Table A5. The aggregated ecotypes were screened for contiguous groups of at least 3 by 3 pixels. Sample locations were chosen randomly in these areas of contiguous pixels within 5 km of the base camp established at the lake, and at least 500 m from another plot from the same stratum. Potential plot locations were generated in excess of what would be possible to sample in the time available, and the locations were assigned random numbers. The crew attempted to reach multiple examples of each type present at each landing site in the time available, with more effort devoted to types known to be not available at other landing sites. One to three plots were sampled per day, and the choice of plots from the larger set of potential plots sought both plots with low random numbers and plots that could be linked by an efficient route in a day's work.

Table A5. Land cover stratification of lichen plots in GAAR

Aggregated Ecotype	Count of Plots by GIS Class[1]	Count of Plots by Revised Class[2]	Original Ecotypes[3]
Alder/Willow	5	6 (includes broadleaf forest)	Lowland Alder Tall Shrub
			Lowland Willow Low Shrub
			Riverine Alder or Willow Tall Shrub
			Riverine Birch-Willow Low Shrub
			Riverine Willow Low Shrub
			Upland Alder-Willow Tall Shrub
			Upland Willow Low Shrub
Broadleaf forest	3	(joined with Alder/Willow)	Riverine Poplar Forest
			Riverine White Spruce-Poplar Forest
			Upland Birch Forest
			Upland Spruce-Birch Forest
Dwarf Shrub Acidic	14	14	Alpine Dryas Dwarf Shrub
			Alpine Ericaceous Dwarf Shrub
			Riverine Dryas Dwarf Shrub
Exclude	0	0	Alpine Lake
			Alpine Wet Sedge Meadow
			Lowland Ericaceous Shrub Bog
			Lowland Lake
			Lowland Sedge Fen
			Riverine Barrens
			Riverine Water
			Riverine Wet Sedge Meadow
			Shadow/Indeterminate
			Snow

[1] The count of plots using the classification of the plot location as mapped by Jorgenson et al. (2009)

[2] The count of plots in each class after correction of the plot classification based on field data, and aggregation of Alder/Willow + Broadleaf Forest, and Low Birch Ericaceous + Tussock Tundra.

[3] Classes are from Jorgenson et al. (2009)

Table A5 (continued). Land cover stratification of lichen plots in GAAR

Aggregated Ecotype	Count of Plots by GIS Class[1]	Count of Plots by Revised Class[2]	Original Ecotypes[3]
Low Birch Ericaceous	9	19 (includes Tussock Tundra)	Lowland Birch-Ericaceous-Willow Low Shrub
			Lowland Sedge-Dryas Meadow
			Upland Birch-Ericaceous-Willow Low Shrub
			Upland Sedge-Dryas Meadow
Needle Leaf	10	12	Lowland Black Spruce Forest
			Riverine White Spruce-Willow Forest
			Upland White Spruce Forest
			Upland White Spruce-Lichen Woodland
Sparse Vegetation Acid	12	14	Alpine Acidic Barrens
Sparse Vegetation Basic	9	11	Alpine Alkaline Barrens
Sparse Vegetation Mafic	7	3	Alpine Mafic Barrens
Tussock Tundra	10	(joined with Low Birch Ericaceous)	Upland Dwarf Birch-Tussock Shrub

[1] The count of plots using the classification of the plot location as mapped by Jorgenson et al. (2009)

[2] The count of plots in each class after correction of the plot classification based on field data, and aggregation of Alder/Willow + Broadleaf Forest, and Low Birch Ericaceous + Tussock Tundra.

[3] Classes are from Jorgenson et al. (2009)

Because of the significant effort involved in reaching each plot, the crew did not reject plots that turned out to not belong to the targeted ecotype. Instead they sampled the plot and later re-classified it (Table A5). For data analysis Nelson et al. (2015) aggregated the 9 types further, resulting in 7 types for analysis. Broadleaf forest and Alder/Willow were aggregated in view of their similarity and the small sample size of the former (just one after reclassification); Low-birch Ericaceous and Tussock Tundra were also aggregated due to their similarity and the multiple re-classifications of both types into the other class.

Appendix A References Cited

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Appendix B: Standard Operating Procedures for Vegetation Node Sampling

Standard Operating Procedure (SOP) # 1: Pre-field procedures

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. Data Recorders

To date this project has used two Trimble Nomad data recorders recorders per crew, one for the two botanists running the point intercept device and one for the soil scientist. Data are recorded on three spreadsheets, one for point intercept, one for the soil and site information, and one for trees. Soil horizon descriptions are recorded on waterproof paper. Waterproof touchscreen tablet computers may be preferred for their large screens in the future.

<u>A1. Data files</u>. Load blank data forms onto the data recorders. The forms should be named according to the convention XXXptsTrans#.xls, XXXSiteYR.xls, and XXXTreesYR.xls, where "XXX" is the 3-letter abbreviation for the node, # is a sequential number for the transect and "YR" is the 2-digit year. Ensure that the vascular plant choice list in XXXptsTrans#.xls is the NPS species vascular plant list for the park where the node is located. The data forms should go in the folder "My Documents\Business\" on the Trimble Nomad.

<u>A2. Spreadsheet software</u>. Because the standard spreadsheet software on Trimble Nomad data recorders (Microsoft Excel Mobile) does not at this time support drop-down choice lists, we are using a similar shareware program called "SpreadCE" (http://www.byedesign.co.uk/), the operation of which is very similar to Microsoft Excel. SpreadCE is run directly from the executable file "SpreadCE.exe", stored in the folder "My Documents\Business\".

A3. Some tips on running the Trimble Nomad data recorders and SpreadCE.

A3.1. The on/off buttons. There are 4 different modes that the Nomad can be in: shut down, suspended, on with backlight off, and on with backlight on. During field operations the Nomad is on continuously and suspended between plots and at night. (We generally do <u>not</u> shut the units down at night because one can accidently reset the unit – erase the memory – when trying to shut down.) To suspend, hit the green on/off button briefly so that the screen goes completely blank (if you hold it too long, the backlight goes off but the unit will not be suspended – you can still see characters on the screen. To restore, hold the on/off button until the backlight comes on (sometimes the backlight comes on with a single hit, but often you have to hold it for about a second).

A3.2. Managing the memory. When you “x” out of a program in Windows Mobile, it actually continues to run in the background. You may thus accidently have several programs running that you don’t need. Each evening after backups have been completed you should clear the memory of running programs by selecting Start, Settings, System, Memory, Running Programs (tab).

A3.3. Battery level. A small icon indicating the battery level is visible in the upper right-hand corner of the desktop. To get a better indication of battery level, select Start, Settings, System, Power.

A3.4. File management. Files are copied and renamed using File Explorer. Tapping a file with the stylus will open it (and thus not allow you to copy it). To select a file to copy or rename it, use the arrow keys to highlight it and then use the stylus to select Menu (bottom right of the screen), then Rename or Edit-Copy, -Paste, etc. If you tap an xls data file in File Explorer, it will open in Excel Mobile. If this happens, even if you close the Excel window Excel will continue to run in the background until you shut it down using the memory manager as described in step A3.2 above.

A3.5. Using SpreadCE. SpreadCE is run directly from the executable file “SpreadCE.exe”, stored in folder “My Documents\Business\” along with the current data files. Use the File Explorer to navigate to SpreadCE.exe and touch this file with the stylus to open it. Next use File, Open, and touch your file name. Be careful not to open a backup copy by mistake.

For details on the spreadsheets, see the SOPs below for point, site/soil, and tree data entry.

In SpreadCE, be sure that all the worksheets used to record data in the form have been formatted so that the column and row headings are hidden, to allow more of the form to show on the screen: select Format, Sheet, and then uncheck “Headings”.

B. Equipment

B1. For two plant technicians:

- Two 15 m measuring tapes with string extensions to 16 m. 1-m points should be marked with brightly colored tape for photographs
- Trimble Nomad data recorder with PDA keypad and stylus
- 1 gallon plastic bags for plant samples
- 5 survey pins with carrying case
- 2 sighting compasses
- Hand lens
- Tags for plant specimens

- Pencils

- 2 Waterproof laser pointers. The plastic Lasermate pointer is available from www.genaldi.com or www.lasermate.com.

- Rod and holder for the laser. These are made from hardware-store materials. The rod should be stiff enough to pushed into soft soil and long enough to allow sightings up to about 1.5 m. A bracket made from plastic plumbing fittings holds the laser vertical (Fig. B1). A 50-cm piece of ½-inch PVC pipe with a mark at 20 cm is used as a guide for recording plant heights. The pipe slides up the rod when the latter is pushed into soft ground. A short piece of string tied to a hole in the pipe and taped to the rod keeps it from sliding off the rod during transport.

- Densitometer. A periscope-type sighting densitometer that can be placed on the laser bracket. The GRS densitometer (www.grsgis.com) serves well for this purpose (Fig. B2).

- A rod 3 mm in diameter and 15 cm long, with ruler for lichen mat height measurements.

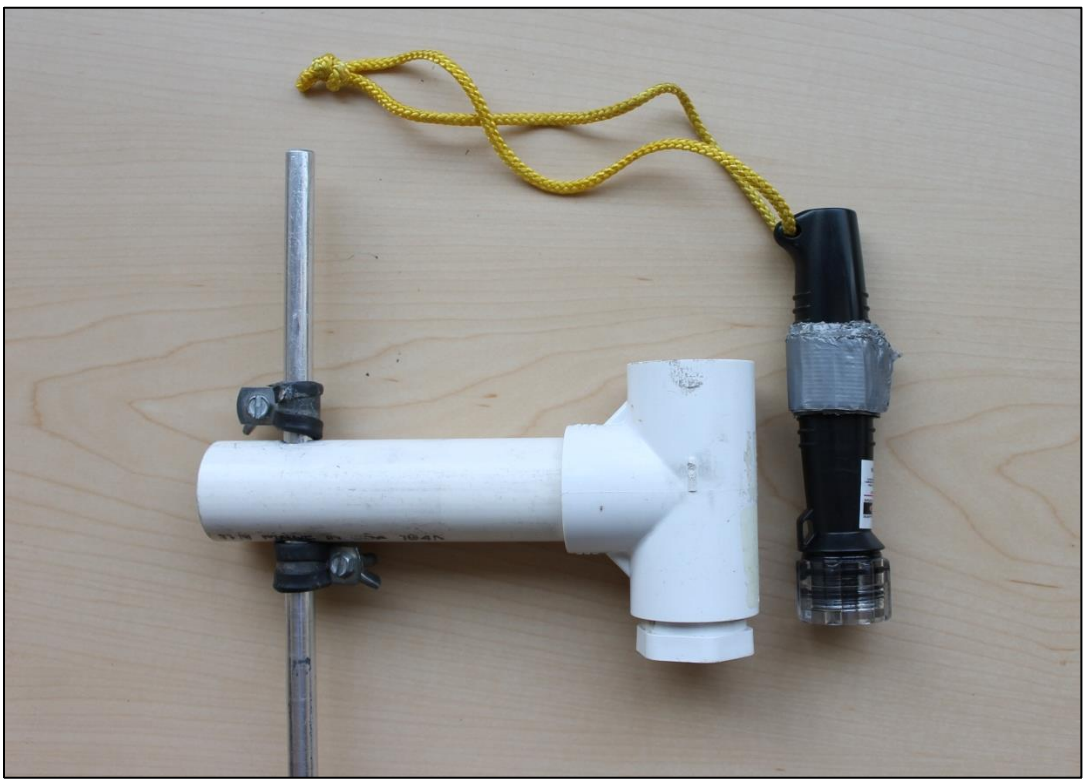


Figure B1. Point-intercept sampler. The holder is made from standard 1 inch plastic pipe and fittings. The waterproof laser pointer fits inside.

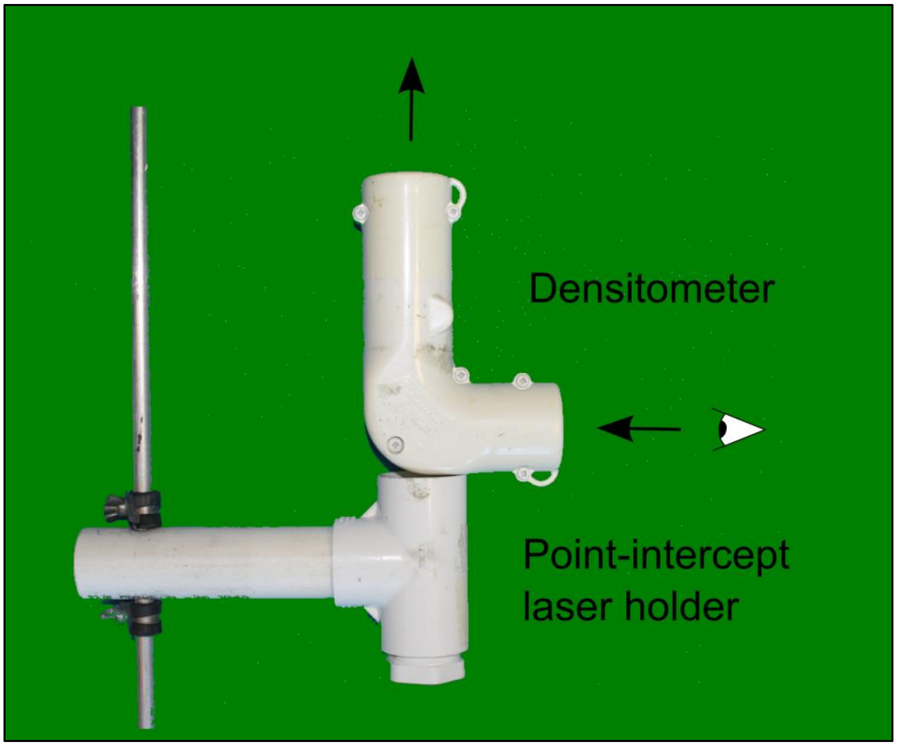


Figure B2. Point-intercept sampler with densitometer for overhead sampling.

B2. For the soil-site-tree technician. Objects marked with an asterisk “*” are not required for revisits to existing plots that already have a soil description. Objects marked with a pound sign “#” are required only where trees are present:

- Trimble Nomad data recorder with number keypad and stylus
- Trimble GPS, mapping grade (for 1 m accuracy in locations)
- Recreation-grade GPS (for 5-10 m accuracy in locations)
- Magnetic detector (for relocating existing plots only)
- *Shovel. A narrow sharpshooter-type shovel is best.
- *Soil auger. The AMS 3 ¼” bucket auger http://www.ams-samplers.com/ works well. Handles should allow excavation to 1 m depth. The auger can be omitted from transects that are dominantly rubbly materials or near-surface permafrost.
- Soil tile probe. Inexpensive steel push probes with a T-handle are available from multiple manufacturers. Of the common sizes, the 4-foot (122 cm) length is most appropriate.
- Camera with memory cards, remote camera shutter switch, and waterproof cover. Bring a 4 GB memory card for each node.

- Camera pole. The camera pole is made from an 18 foot painters extension pole custom-equipped with a 1/4-20 standard screw thread for attaching to the camera (Fig. B3)
- *Soil profile description forms on waterproof paper
- Clipboard, form-holder type
- Clinometer
- Compass
- 2 m tape measure
- Pencils
- *Hand lens
- Magnetic plot markers (available from Surv-Kap www.surv-kap.com)
- *Soil pH kit, Morgan type with 4 indicators available from LaMotte (www.lamotte.com). (The LaMotte kit includes a 5th wide-range indicator that is not needed.)
- *Ceramic spot plate, 12-hole. The one manufactured by Coors is widely available
- *Munsell soil color book
- Waterproof pocket notebook
- #Calipers for small tree diameter measurement
- #2 tree dbh tapes
- #Tree distance measuring device and target (SONIN® Combo Pro, Hagloff® DME or equivalent)
- #Tripod for tree measuring target

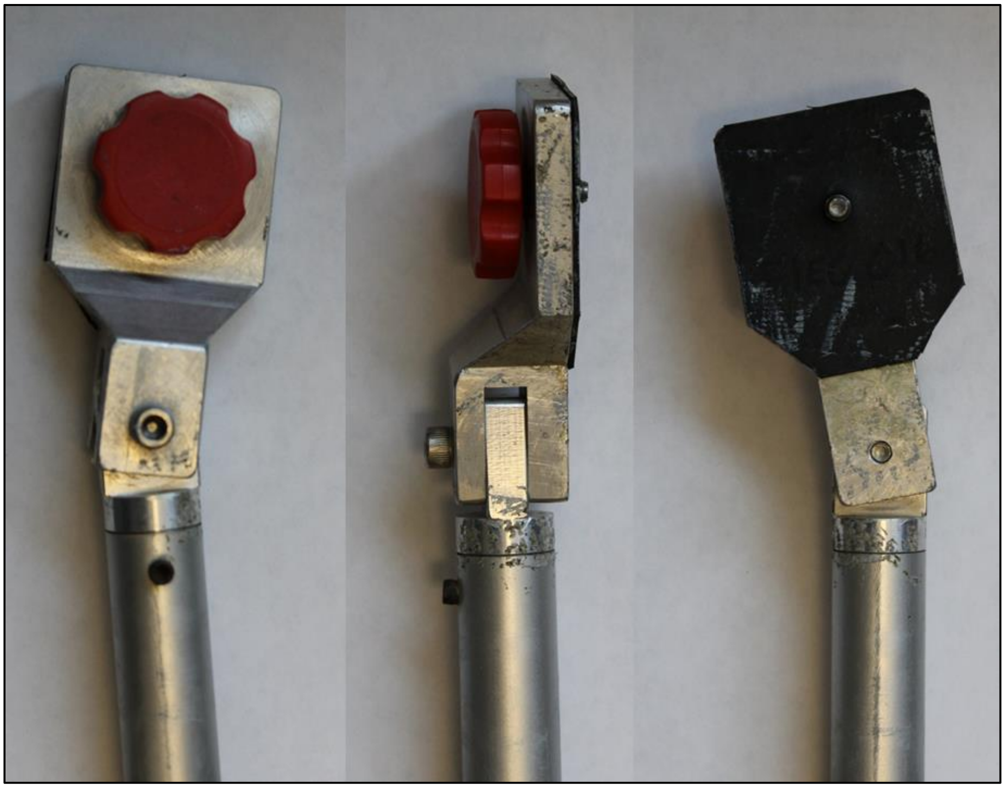


Figure B3. Adapter machined for a standard painter's pole to attach a camera for plot photographs.

B3. For the crew:

- Satellite or aerial photo images of node
- Topographic maps
- Field laptop for photo and data file backups, and associated USB cables
- Plant press and supplies. Plan for between 25 (in non-coastal lowland areas) and 75 (in the mountains) collections per node.
- A few paper bags for nonvascular specimens
- Spare Trimble stylus
- Expandable file for papers
- Spare batteries. Battery needs are as follows:
    - The point-intercept Trimble Nomad needs 1 battery per each 2 or 3 days of sampling
    - The soil-site-tree Trimble Nomad can go about a week on one battery

  - The Trimble GPS can go about a week on the internal battery if used only briefly at each plot to obtain accurate coordinates and not for navigation. Be prepared for unexpected discharges, however.
  - The Garmin GPS can go several weeks on 2 AA batteries
  - Camera batteries should be carried as needed for the particular camera
  - The Sonin distance measuring device will work multiple nodes on a single 9V battery

- Battery re-charging equipment for other devices. Inspired Energy CH7000 solar charger and at least 2 NL2024 14.4V Lithium batteries. About 50 W of solar panel capacity with vehicle adapters to all electronics requiring recharge. Or bring sufficient charged NL2024 14.4V batteries to last the trip and omit the solar charger. You will need at least one charged NL2024 for every 5 days of fieldwork.

- The Trimble GPS may also be recharged by direct connection to the Inspired Energy NL2020 10.8V Lithium battery with Trimble adapter. *Be careful not to connect it directly to a 14.4 V battery without a vehicle adapter*.

- Safety equipment: flight vests, first aid kit, satellite telephone, aviation safety plan, emergency contact list

- Plant identification references (vascular and nonvascular)

C. Node selection

C1. Existing nodes were selected based on the criteria outlined in section 2.1 above. Any new nodes should be established by similar criteria and to improve coverage of uncommon environments, as shown in Table 1.

C2. Proposed transect and campsites are digitized in the GIS prior to fieldwork. Latitude and longitude coordinates are generated from these points, printed out for the pilot, and loaded onto the GPS. In the current version of ArcMap (v. 10), add (if necessary) columns to the attribute table of the node GIS layer columns named something like POINT_X_DD and POINT Y DD, both double variable types. Right-click on each column and select "Calculate Geometry" to compute the x and y coordinates of each point. Degrees decimal minutes are most familiar to most pilots, while decimal degrees are most easily imported into our GPS.

C3. Load the latitude and longitude of the nodes onto your recreational-grade (Garmin) GPS. Garmin GPS waypoints are currently uploaded using the State of Minnesota DNR software package called "DNRGarmin", which is available from http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html.

After downloading and installing this software, launch it and choose the menu option GPS, Set Port, and be sure that USB is checked. Plug the GPS to your computer using a USB cable and turn on the

GPS. To connect with the GPS, choose the menu option GPS, Auto Connect to GPS. After working for a few seconds the box in the lower left-hand corner of the menu should read “Connected”.

In DNR Garmin, choose file, load from, file, and navigate to your file. Under “ident” choose the node name, and identify the latitude and longitude columns (decimal degrees) also. The table should appear on the “Data Table” view. Choose Waypoint, Upload to transfer the points to your GPS

D. Transect locations

D1. Background. One transect is placed within each landtype or other physiographic stratum at a node. The project leader chooses an approximate transect starting point, and an azimuth oriented to cross the diversity of habitats available in the physiographic stratum. Transects are located on imagery before field season, but transect locations can be modified or new ones proposed in the field to avoid obstacles, keep sampling closer to camp, or sample features missed by the pre-selected transects. Actual plot coordinates are determined in the field during sampling.

Transects are laid in a zig-zag fashion with 3 plots per leg (2 in special cases where the targeted area is too narrow to accommodate 3) (Figs. 5 and 6). Transects should contain at least 4 plots, and the number of plots should be chosen to represent a full day’s of work. For example, in typical tundra environments a crew of three can do 4 plots in a day, so transects usually contain 4 or 8 plots.

The plot spacing is chosen as needed to cover a representative part of the physiographic stratum, typically 100 or 200 m. When planning transects, keep in mind that (for a normal transect with a 90° change in direction every 3 plots; Fig. 6) the transect will require a rectangular area with width about 1.4 times the plot spacing and length per plot equal to about 0.7 times the plot spacing. Thus an eight-plot transect with 200 m spacing requires at least 1200 m of distance in a physiographic stratum, while with 100 m plot spacing we need only 600 m.

E. New Transect Pre-selection

Proposed transect starting points are created in the office and loaded onto the GPS. Transect azimuths are computed relative to true (as opposed to magnetic) north.

E1. Digitize the proposed starting and ending points. In the GIS prior to fieldwork, digitize the starting point and ending point of each proposed transect. Add fields named Node (data type text), Transect (text), Start (Short integer), X_ALB (double), Y_ALB (double), X_DD (double), and Y_DD (double) to the attribute table. Fill in the node abbreviation, name the transect something mnemonic (like “floodplain” or “slope”; it need only be unique at the node), and label the points as the start (1) or end (2) of the transect. Right click on POINT_X_ALB and choose Calculate Geometry to bring up a dialog box. Choose “Property: X Coordinate of Point”, use the coordinate system of the data source (Alaska Albers) and units of meter. Repeat for POINT_Y_ALB, except now choose “Property: Y Coordinate of Point”. Next right-click on POINT_X_DD and choose “Property: X Coordinate of Point”, use the coordinate system of the data source and units of Decimal Degrees. Repeat for POINT_Y_DD using the y coordinate property and decimal degrees again.

E2. Export transect start coordinates to the GPS. Export the attribute table to a spreadsheet, extract just the Node, transect, X_DD, and Y_DD columns. Merge the Node and transect into a unique identifier for each transect start, and save as comma-delimited text with a *.txt extension. Be sure to save column names in the first line, as DNR Garmin will cut these off. Load the X_DD and Y_DD points on your recreational-grade (Garmin) GPS by the same procedure as outlined above for the node locations. In DNR Garmin, choose file, load from, file, and navigate to your file. Under "ident" choose the transect identifier (merged node abbreviation and transect names), and identify the latitude and longitude columns also. The table should appear on the "Data Table" view. Choose Waypoint, Upload to transfer the points to your GPS

E3. Compute the proposed transect midline azimuth. For most people this is most easily done by exporting the attribute table of the transect start/end point layer to a spreadsheet, though the computations can also be done in the GIS. Be sure the data are sorted by Node, Transect, and Start so that the start and end of each transect occur consecutively. The proposed transect azimuth is computed using the arctangent function from the Alaska Albers coordinates. For example, if the x-coordinate (i.e., POINT_X_ALB) is in column F and the y-coordinate in column G, the start of the transect on line 2 and the end on line 3, the spreadsheet expression is:

```
=DEGREES(ATAN((G3-G2)/(F3-F2)))
```

The "degrees" function converts from radians to degrees. This expression will return angles measured from the east-west line and some will be negative. To convert them to positive azimuths from true north, subtract all easterly azimuths from 90 and all westerly azimuths from 270 using this expression:

```
=IF(J2>0,90-L2,270-L2)
```

for a spreadsheet where cell J2 contains the difference in x-coordinate between the start and end of the transect (i.e., a positive number indicates an easterly transect) and L2 contains the result of the DEGREES-ATAN formula above.

Print the proposed transect starting point latitude and longitude, and the proposed transect midline azimuths.

E4. Transect randomization and plot location. The actual plots locations are derived from the proposed transect start and midline by a series of dice rolls and computation. These may be performed in the office prior to fieldwork or in the field, and they are listed below with field procedures in SOP #2. If they are performed in the office, make a sketch map with the necessary coordinates and azimuths and take it to the field with the node maps. In the office, you can use the spreadsheet formula "`=RANDBETWEEN(1,6)` to return numbers like a dice roll.

F. Existing plot re-visits

Dates of plot re-visits should be as close as possible to the original sampling dates. Thus it makes sense to group the nodes to be visited in a particular summer as they were in the first visit, and follow the same sequence of nodes through the summer. The date information for each node can be obtained from the database.

For re-visits we navigate to existing plot coordinates; information on the transect azimuths used to originally locate the plots is not needed. Query the coordinates for existing plots from the database. Use the differentially corrected coordinates recorded using the Trimble GPS. These coordinates are in the WGS1984 coordinate system that can be directly loaded into the GPS as described in step C3 above. There are a few plots with no Trimble GPS coordinates from the first sample visit (KUZ17, NGC10 through 15); use the recreational-grade GPS coordinates for these.

Query the database Plot table, "PlotNote" field for the word "*magnet*" to locate any notes about any plots where the magnetic marker is missing or placed at some distance from the plot center. Make a print copy of these notes to consult in the field. Bring the photographs from the previous plot visit on a device that allows them to be viewed in the field, to help locate plot centers where the magnet has been lost and for aligning transects.

The sample lines within a plot were originally oriented to the magnetic cardinal directions, and due to drift of magnetic north this may have changed. Compute the current magnetic declination for the plots that will be resampled, using the procedure described in SOP #7, section I. Average the current declination for the plots at a node and compare to the declination from the initial visit (in the database, Node table, Declination1 column). Compute the difference between the current and initial declination and provide it to the field crews. Be careful to provide the correct sign for the correction. Our sighting compasses have no declination adjustment, so the adjustment is made to the azimuth that you sight toward. At the present time declination is decreasing by about 3° per decade in our area. If current declination is 3° less than the initial declination, the correction is *positive*, the field worker should aim the sighting compass at +3°, +183°, +93°, and +273° to reproduce the original transect azimuths.

Standard Operating Procedure (SOP) # 2: Node, transect, and plot establishment

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. New transect randomization

A1. For transects established in the field, use a compass to select a proposed transect midline azimuth, either from the map or by sighting from the starting point. If sighting from the starting point, remember to adjust for declination. Transect azimuths are relative to true north. For transects chosen in the office, refer to the proposed transect midline azimuth computed in SOP #1.

A2. Randomize the transect midline azimuth by dice roll. Add or subtract the value in the following table from the proposed transect azimuth. The final azimuth with be within plus or minus 10° of the proposed azimuth. Record the actual transect midline azimuth and back azimuth (the azimuth notebook 180° in your field notebook.

Dice roll	Azimuth add/subtract
1	-10°
2	-6°
3	-2°
4	+2°
5	+6°
6	+10°

A3. Select distance to the first plot and direction (right or left) of the first leg by dice roll:

Dice roll	Leg direction	Distance, in multiples of the plot spacing
1	R	1/4
2	R	1/2
3	R	3/4
4	L	1/4
5	L	1/2
6	L	3/4

A4. Make a transect layout sketch in your field notebook. The first plot is a transect midline plot. The starting leg direction is either left (as in Fig. 6) or right. The transect leg azimuths will be:

- (right leg azimuth) = (midline azimuth) + 45°
- (left leg azimuth) = (midline azimuth) - 45°.

Record these azimuths and their corresponding back-azimuths (azimuth – 180°) in your field notebook. Adjust the azimuths that are negative or >360 as needed.

B. New plot location

B1. Navigate to the proposed transect starting point by GPS using the waypoints stored in SOP #1 above (for transects chosen in the office) or by walking to your preferred spot and marking a waypoint(for transects chosen in the field).

B2. Go to the first plot. Use the Find Waypoints function on the Garmin GPS. Travel *away* from the proposed starting point (waypoint) until the proper distance and back-azimuth are obtained (consult your sketch from step A above). Your GPS should be set (as it normally is) to give azimuths relative to true north. When walking away from a waypoint, veer right to increase the back-azimuth, left to decrease it. Move slowly when approaching the desired azimuth and distance to allow the GPS to equilibrate. Stop when both the azimuth and distance first reach the desired values. Mark the Garmin waypoint and set up the Trimble GPS to get a more exact location.

B3. Place the magnetic plot marker in a shallow slot approximately 10 cm deep. Note that the black end of the magnet is marked “this end down”. Place a survey pin at plot center.

B4. Navigate to the next plot (after sampling is completed). Consult your sketch to determine if you are on a left or right leg and choose the appropriate back-azimuth. Using the Find Waypoints function with the previous plot as the waypoint, and go until the desired distance and azimuth are obtained as described in step B3 above, consulting your transect sketch from SOP #1.

B5. Deliberately chosen plots. If time allows at a node, place additional plots in communities of interest that were missed by the systematic sampling. Mark the plots with a magnetic marker and

Trimble GPS as described previously. Note in your sampling book that the plot was located deliberately.

C. Existing plot location

Navigate to existing plots with a recreational-grade GPS. When you are within a few meters of the plot according to the GPS, activate the magnetic locator to locate the buried magnetic plot marker and place a pin in the ground above it. Where notes indicate that the magnet is offset from the plot center (see SOP #1, Pre-Field Procedures, part F; this is rare), adjust the location according to the notes. Where the notes indicate no magnet was placed, use the Trimble GPS to get as close as possible to the original location, consult photographs to confirm the location, and place a magnetic marker if conditions allow. If the magnet does not appear to be where it should be, consult the photographs to confirm that you are in the right place. If it appears that you are and the magnet has been lost or moved, get as close as possible to the original location with the Trimble GPS and photos, place a new marker, take a new Trimble GPS location, and record what you did in the notes.

D. Plot layout

Orient the two tape measures by magnetic azimuth, north to south (north is the zero end of the tape) and west to east (west is the zero end; Fig. 8). The plot center stake should be at the 8 m mark on the tapes. Use survey pins to mark the transect ends. We are using 15 m tapes so an additional short measuring tape will be used for the point intercepts between 15 and 16 m.

During plot re-visits, use the photography from the previous visit along with the compass to locate transect azimuths that match the previous visit. Use the azimuth correction factor computed in SOP #1, part F when sighting with the compass. In recent decades declination has been decreasing, which leads us to use a *positive* correction factor. A positive correction factor means both true north and current magnet north will lie to the left (counterclockwise) of the original transect magnetic north-south line. If the correction is positive, you should add that amount to the cardinal directions (0°, 180°, 90°, and 270°) and sight to these "larger" azimuths. For example, a correction factor of +4° means that you should sight and align to the tape to the azimuths 4°-184° and 94°-274°. Don't be confused by the fact that in the viewfinder of the sighting compass, these higher azimuths appear to the *left* of the cardinal azimuths. Also note rocks, shrubs, or trees in the photographs to help align the tape.

E Node, transect, and plot notes

We have places in the database for notes about node access (e.g., travel time, landing area suitability), node camp (suitability of the campsite), node natural features, transect access (the nature of terrain that one must cross to reach a transect and time required), transect natural features (summary of the vegetation and terrain of a transect), plot vegetation, plot soil. All of these notes are made in pencil in waterproof notebooks (with the exception of the soil notes, which can be on the soil form). Feel free to record any information that you find interesting and that may be useful to future crews. Be sure to record any irregularities or errors in sampling.

Standard Operating Procedure (SOP) # 3: Photography

Version 1.0 (Xxx 2010)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. Camera settings: set the camera for shutter speed priority, automatic ISO setting, and autofocus.

B. Photo sequence. Shoot the following photos in this sequence

B1. From the plot center, magnetic N, NE, E, SE, S, SW, W, NW. Use a 1/60 sec shutter speed unless vegetation is waving rapidly in the wind, in which case a 1/125 or 1/250 sec speed is desired (For some technicians it may be best to leave the shutter speed at 1/250 sec for all photos.). Shoot with lens zoomed to wide angle (18 mm on the Canon Digital Rebel SLR camera). Try to position the photo frame so that a small strip of sky is visible at the top of each photograph, but raise the camera no higher than the point where the transect end is at the photo center.

B2. Pole photos of magnetic N, NE, E, SE, S, SW, W, NW. These are shot from a pole 5.2 m above the ground (Fig. B3). Shoot with camera zoomed to wide angle (18 mm on the Canon Digital Rebel SLR camera) with the portrait orientation so the wide dimension of the photo is radial to the plot center. Set the camera view angle so that with the pole collapsed the edge of the field of view is about 20 cm from the pole base. Set the shutter speed at 1/250 sec unless this results in too little light. If needed, in high winds use two helpers with cords to guy out and stabilize the pole. In the rain use a waterproof camera cover.

B3. Transect end photos. From about 2 m outside the transect ends looking toward the plot center. This is to record landmarks such as rocks that can be used to locate the ends in subsequent years. Shoot wide angle photos with the camera in portrait orientation so the tape is visible from the end to the plot center. Switch the shutter speed back to 1/60 for these and the following photos.

B4. Plot center photo from above, if there are features near the plot center that will be useful in locating the center in future years (e.g., rocks).

B5. A soil profile photo with scale in 10-cm increments visible on the photos. A flash will often be required. Where the water table is near the surface and a core-shaped section of soil can be removed intact, photograph the core with scale laying on the ground surface.

C. Photo notes and errors. Record any issues with the photos (e.g. photos were shot starting from an azimuth other than north) in pencil in a waterproof notebook. *Do not* delete photos if you make a mistake like this. Re-shoot photos as needed and make notes about the error. Any unneeded photos can be deleted later in the office, after backups have been made.

D. Photo backups. Backup photos to a field laptop each evening and leave the photos on the camera's memory card also. Switch cards at each new node.

<u>D1. Storage requirements</u>. Each plot requires about 22 photographs. Thus assuming 5 MB photograph files just over 2 GB of camera memory is needed for each node of about 20 plots. Bring enough memory cards to accommodate all photos without erasing any from the cards.

Standard Operating Procedure (SOP) # 4: Site Attributes and Soil Description

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. General

Site attributes are recorded on a Trimble Nomad data recorder with number keypad. The file name is "XXXSiteYR.xls", where "XXX" is the 3-letter abbreviation for the node and "YR" is the 2-digit year. A single file will be used to record all site data from a node in a season. The list below includes the abbreviations for the data elements used on the spreadsheet to minimize screen area occupied. Each plot occupies a column; scroll to the right to view subsequent plots.

B. Data Elements

<u>Plot</u>: the sequential plot number. Each plot has one column on the entry spreadsheet, and the columns are later converted to records (rows) in the database.

The next 12 fields on the spreadsheet are geomorphic descriptors from the USDA NRCS Geomorphic Description System (Schoeneberger and Wysocki 2012). The system has 3 levels of landforms (landscape, landform, and microfeature). Our data entry form allows for one landscape (LS), 4 landforms (LF1, LF2, LF3, and LF4), and 2 microfeatures (MF1 and MF2). Those are chosen from long lists that are shortened by choosing an environment in the first column of the data entry sheet (which has no plot number above it). These environments are not saved, they are only used to narrow the choice lists. Multiple landforms and microfeatures can be recorded because they can be superimposed at a site. For example, a flood plain landform may have patterned ground landform in it.

<u>Comp</u>: geomorphic component (Fig. B4). This field also operates via an intermediate choice that narrows down the choice list.
<u>Pos</u>: position on the slope: (Fig. B5). Use NA for level areas that are not part of a slope.
<u>ShpVt</u>: slope shape (concave, linear, convex) in an up-downslope direction. "Linear" indicates no curvature.
<u>ShpHr</u>: slope shape parallel to the elevation contours.

FldFrq: flooding frequency: None – flooding is impossible, Very Rare – possible but <1 time per 100 years, Rare – 1 to 5 times per 100 years, Occasional – 5 to 50 time in 100 years, Frequent - >50 times in 100 years.
Veg1: vegetation classification. Viereck et al. (1992) level IV vegetation class for the whole plot if only one class present, or one of two if two are present.
Veg2: Viereck et al. level IV vegetation class for the second class if two are present.
Veg1%: proportion of the plot occupied by Veg1.
Vegt2%: proportion of the plot occupied by Veg2.
Aspct: slope aspect. The direction toward which the surface of the soil faces, expressed as an angle between 0 and 360 degrees measured clockwise from true north.
Gradnt: surface slope gradient of the plot, as measured in the steepest direction.
GradN: surface slope of the point intercept transect that trends north from the plot center, measured looking north.
GradS: slope of the transect facing south from plot center.
GradW: slope of the transect facing west from plot center.
GradE: slope of the transect facing east from plot center.
Frzn: depth to frozen material in the soil pit. "999 indicates no frozen soil was observed.
WatTbl: depth to free water in the soil pit. "999" indicates no water table was observed.
Wet: depth to wet soil in which most pores are filled with water and the surface appears wet. Commonly occurs above the water table in fine-grained soils. "999" indicates no wet soil was observed.
HolDep: depth of excavation of the soil pit.
PM1: parent material 1. Genetic composition of the material from which the surface soil formed (Soil Survey Division Staff 1993). Includes general composition information for the residuum class: felsic (felsic igneous rocks - granite, rhyolite, - and related metamorphic rocks – granitic gneiss), mafic (mafic igneous rocks – basalt and gabbro), fine sedimentary (shale), coarse sedimentary (sandstone and conglomerate), calcareous (limestone, dolostone, marble).
PM2: parent material 2. For soils with layered materials, the subsurface (below PM1) genetic composition of the material from which the soil formed.
PM3: parent material 3. For soils with layered materials the third material from the surface.
LichUtl: lichen utilization class (Table B1).

The next 6 fields record information on the level of browsing of woody plants. The system used is an attempt to fuse the systems of Keigley and Frisina (1998) and Seaton (2002). Keigley and Frisina (1998) is used to define the uninterrupted, arrested, retrogressed, and released classes; Seaton is used to define the browsed, unbrowsed, and broomed classes within the uninterrupted class. Table B2 explains this hybrid system.

The choice lists for the browse plants contains all the mid- to tall shrubs that occur in the network, plus the broadleaf deciduous trees.

BrPl1: browse plant 1.
BrAr1: the architecture of browse plant 1.

BrPl2: browse plant 2.
BrAr2: the architecture of browse plant 2.
BrPl3: browse plant 3.
BrAr3: the architecture of browse plant 3.
InitialsSoilSite: initials of the person who did the soil and site description.
InitialsPointsRead: initials of the person who operated the point-intercept apparatus and identified the intercepts. Here and in the next field, if the botanists change roles midway through the plot, record here the person who started in this role.
InitialsPointsRecord: initials of the person who recorded the point-intercept data.
DateTime: the date and time code is written by pressing the button, which runs a macro that writes the date and time from the computer's clock. The format of the time and date is the same as that used by Microsoft Excel. To the left of the period is the day, numbered sequentially from 1 Jan 1900. To the right of the period is the time, as a fraction of the number of seconds in a day. The code of the macro is as follows:

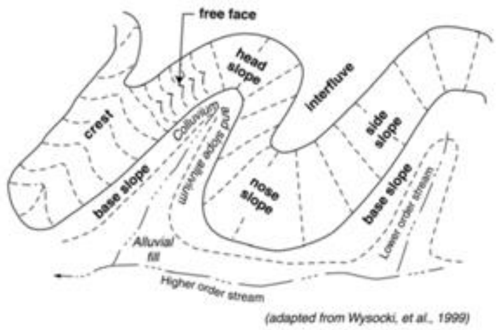
```
=IF(ROW(SELECTION())=41)
=FORMULA(NOW(),INDIRECT(ADDRESS(41,COLUMN(SELECTION()),,,"Data")))
=END.IF()
=RETURN().
```

This macro is linked to a button on a form. It will place the current date and time in the currently selected cell in a worksheet called "Data", if the selected cell is in row 41 (i.e., the row designated for data/time data in this particular form).

G) **GEOMORPHIC COMPONENT :**

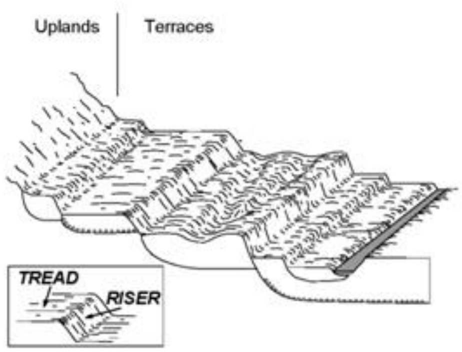
1) HILLS :

interfluve
crest
head slope
nose slope
side slope
free face
base slope



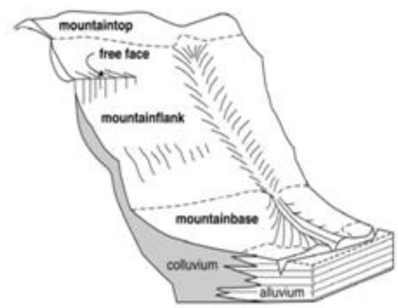
2) TERRACES, STEPPED LANDFORMS :

riser
tread



3) MOUNTAINS :

mountaintop
mountainflank
upper third – mountainflank
center third – mountainflank
lower third – mountainflank
free face
mountainbase



4) FLAT PLAINS

dip
rise
talf

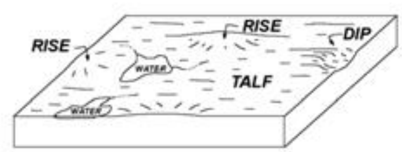


Figure B4. Geomorphic components, used in plot site descriptions.

Table B1. Lichen utilization classes[1]

Class	Description
0 - None	-
1 - Trace	Trace to 5% of the lichen cover is disturbed. There is no apparent trampling or forage use. To determine utilization, a careful examination of the podetia of *Cladina spp*. or thalli of *Cetraria spp*. will be required. No recovery period necessary.
2 - Slight	5%-25% of the lichen cover is disturbed or dislodged. There is no appreciable disturbance to the lichen cover. Careful observations have to be made to detect utilization. Craters are not apparent; a few individual bites are noted.
3 - Moderate	26%-50% of the lichen cover is disturbed or dislodged. Evidence of slight grazing or trampling is apparent. “Top Cropping” may be placed in this class, even if it occurs on all lichen in the plot. Small, shallow craters may occur, but usually use has occurred on less than 1/3 of the top portion of the thallus.
4 – Moderately heavy	51%-75% of the lichen cover has been removed or dislodged. Use of the lichen is apparent and includes heavy top cropping to use some or the entire live portion of the lichen thallus plant. Craters and/or bites may be obvious when viewed from a distance of 20 feet. Scattered bunches and fragments of lichens are distributed around the plot on the utilized areas; a few small bites may penetrate to the organic mat.
5 - Heavy	76%-100% of the lichen has been disturbed or dislodged. Adequate lichen remains in the utilized section of the plot for regeneration. Craters extend only to the top of the organic horizon and not into mineral soil or exposed rock. Severely trampled sites should be placed in this class.
6 – Severely heavy	Most of the lichen cover has been disturbed or dislodged. Craters extend through the organic mat and expose mineral soil. Less than 25% of the plot has mineral soil and/or rock and/or organic material exposed from grazing or cratering. There should be sparse fragments of lichen remaining to initiate regeneration, but regeneration will be slow.
7 - Severe	All of the lichen cover has been disturbed or dislodged. 25%-50% of the plot has mineral soil and/or rock exposed from grazing or cratering. Inadequate fragments of lichens remain to initiate regeneration at a normal recovery rate. The micro-environment has been altered. Most shrubs have been browsed heavily and bark may be removed.
8 - Extreme	All of the lichen cover has been disturbed or dislodged. 50%-100% of the plot has mineral soil and/or rock exposed from grazing or cratering. There is not adequate lichen for regeneration. This class of utilization occurs only in the most severe circumstances. Recovery period may be 50 to 100 years or more, depending on the soils potential to produce lichen. Vegetation or soil damage may be irreversible, resulting in an altered potential plant composition.

[1] from unpublished scale by J. D. Swanson of the USDA-NRCS, Anchorage, Alaska. Summarized in Swanson and Barker (1992)

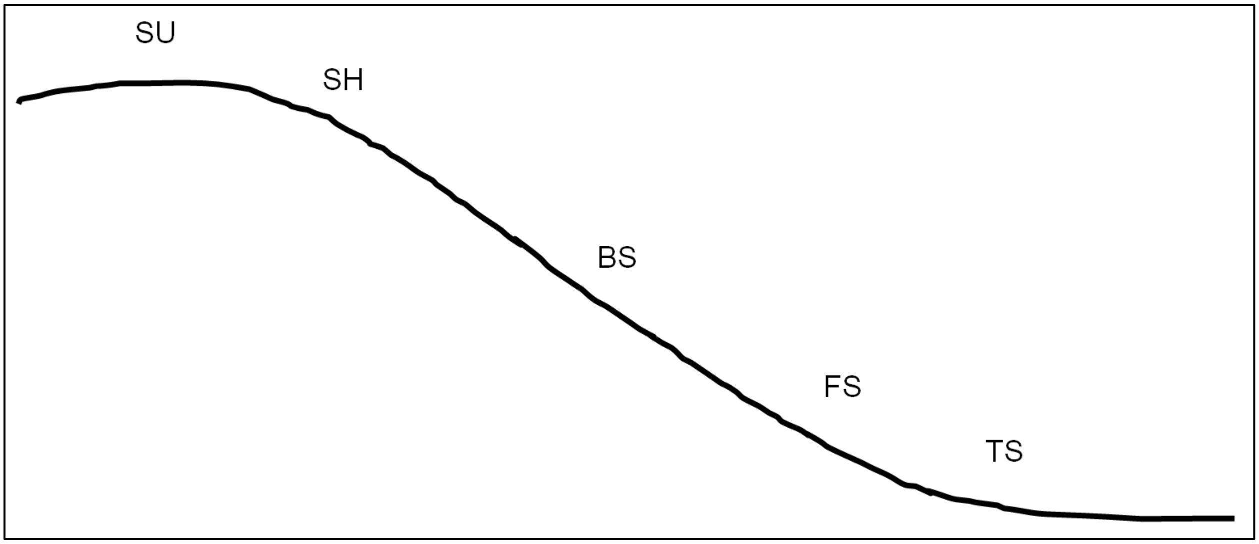


Figure B5. Slope position definitions and codes. SU – summit, SH – shoulder (convex area near summit), BS – backslope (midslope area without curvature), FS – footslope, concave area below backslope, TS – toeslope, concave area with more gentle slopes than footslope.

Table B2. Browse plant architecture classes[1]

Abbreviation	**Description**
	Uninterrupted: produced by light-moderate browsing[2]
UnintNobrowse	Unbrowsed: no signs of being browsed prior to the current year
UnintBrowse	Browsed: show evidence of browsing in past years, but less than half of current annual growth twigs between 0.5 and 3.0 m arise from lateral stems that were produced from browsing
UnintBroom	Broomed: more than half of current annual growth twigs between 0.5 and 3.0 m arise from lateral stems that were produced as a result of browsing. Plant still gains height every year.
Arrest	Arrested: produced by intense browsing[3] throughout the life of the plant. Usually "broomed" as defined above except that height is static.
Retro	Retrogressed: produced by a change from light-moderate to intense browsing while the terminal leader is still in the browse zone. The plant grew beyond the height where continuous intense browsing would normally stop it, but before it grew large enough to escape browsing, height growth was halted or the height reduced by killing of top branches.
Release	Released: produced by a change from intense to light-moderate browsing. The plant was previously *Arrested,* then began adding height every year through new growth originating from the preceding year's segment

[1] after Keigley and Frisina 1998, Seaton 2002

[2] Light- to moderate browsing – part or none of the current year's growth segment is killed by browsing. Each year's annual segment develops from the preceding year's stem segment.

[3] Intense browsing – a complete annual growth segment is killed. Most new growth arises from stems that are more than 1 year old. Includes stems where current annual growth of the leader is killed and lateral branch assumes apical dominance even if some current annual growth on the lateral branch survives.

C. Soil Description

C1. A soil pit will be excavated on the first plot visit, at the center of each plot if soil is present. The soil pit is omitted if the plot center is bedrock or rock with no interstitial material, or if the plot has archeological artifacts (soil pits are omitted from the entire CKR node – Cape Krusenstern). If possible, excavate to about 50 cm depth with a sharpshooter-type shovel and then continue to 1 m depth using a 3 ¼” bucket auger. Holes may be shallower where frozen soil or rock inhibit excavation. The soil is described by following the guidelines in the USDA Soil Survey Manual (Soil Survey Division Staff 1993) and Schoeneberger et al. (2012) using a form (Fig. B6) copied onto waterproof paper. A form with the codes and definitions is used with the soil description form (Fig. B7). Note that several data elements obtained from the soil pit are recorded on the data recorder as a part of the site attributes listed above. These are the depth to water table, depth to wet soil, depth to frozen soil, and depth of excavation. Soil photography is covered in SOP #3. Write any observations of interesting features not covered by the description as notes on the description form.

C2. To minimize impacts on the plot, the soil pit should be no larger than about 50 cm in diameter. If possible, the organic surface layers with vegetation should be removed intact and replaced intact after the soil pit is refilled. The subsoil should be piled carefully on a tarp and placed back in the pit, cleaning the ground surface as well as possible. All disturbance from the soil pit should be within 2 m of the plot center. The soil description is not repeated on subsequent plot visits.

D. Field Data Backups

Each evening following field work, a backup copy of the site data spreadsheet containing data cumulative to that date should be saved in a folder named for the node on the data recorder and on the field laptop. *These files must be given new names daily to avoid overwriting*. The daily backup files should thus be named “XXXSiteDayMonYr.xls” where XXX is the node abbreviation and Day, Mon, and Yr are appropriate for the date. The original file “XXXSiteYr.xls” remains in the data recorder’s in the folder “My Documents\Business\” until the node is complete, when it is moved to the node folder and a new file is started. At the time of the backup, check battery status and also close any running programs using *Start*, *Settings*, choose the *System* tab, then choose *Memory*, and finally choose the *Running Programs* tab.

E. Return visits

On return visits certain data elements *must* be re-measured (labeled “yes” in Table B3), some are optional (labeled “optional” in Table B3), and others should *not* be re-measured (labeled “no”). The optional fields are the site characteristics that in principle do not change, but may be updated if desired. The “no” data elements in Table B3 are data elements that require a soil pit, which should *not* be dug on return visits. A push-probe is used to determine depth to frozen soil on the revisit. Probing is only meaningful in loamy or organic soils with few coarse fragments. Probe in a typical location near the plot center but not disturbed by the original soil pit if the latter is visible.

Table B3. Sampling of site characterstics on return visits.

Data Element	Repeat Sample[1]
Plot	yes
LS	optional
LF1	optional
LF2	optional
LF3	optional
LF4	optional
MF1	optional
MF2	optional
Comp	optional
Pos	optional
ShpVt	optional
ShpHr	optional
FldFrq	optional
Veg1	yes
Veg2	yes
Veg1%	yes
Veg2%	yes
Aspct	optional
Gradnt	optional
GradN	optional
GradS	optional
GradW	optional
GradE	optional
Frzn	yes, by probe
WatTbl	no
Wet	no
HolDep	no
PM1	no
PM2	no
PM3	no
LichUtl	yes
BrPl1	yes
BrAr1	yes
BrPl2	yes

[1] "Yes" indicates that re-sampling is required on return visits; "optional" means it may be re-sampled if desired; "no" means it should *not* be re-sampled

Table B3 (continued). Sampling of site characterstics on return visits.

Data Element	Repeat Sample[1]
BrAr2	yes
BrPl3	yes
BrAr3	yes
InitialsSoilSite	yes
InitialsPointsRead	yes
InitialsPointsRecord	yes
DateTime	yes

[1] "Yes" indicates that re-sampling is required on return visits; "optional" means it may be re-sampled if desired; "no" means it should *not* be re-sampled

Figure B6. (following page). Form used for field soil description.

Figure B7. (following page). Codes and classes used for field soil descriptions. Based on the USDA Soil Survey Manual (Soil Survey Division Staff 1993) and the Schoeneberger et al. (2012)

Location: Plot: Date: Sampler:

HORIZON	UPDEP	LOWDEP	PRIMOIST	SECMOIST	MOTTLES	MOTMOIST	TEXTURE	%GR	%CB	%ST	PRISTRUC	SECSTRUC	CONMOIST	STICKI	PLASTIC	pH	ROOTS	BOUNDARY

Location: Plot: Date: Sampler:

HORIZON	UPDEP	LOWDEP	PRIMOIST	SECMOIST	MOTTLES	MOTMOIST	TEXTURE	%GR	%CB	%ST	PRISTRUC	SECSTRUC	CONMOIST	STICKI	PLASTIC	pH	ROOTS	BOUNDARY

Horizon
Master: O,A,E,B,C,R,W
OA, AB, etc. indicates intermediate property
O/A, A/B, etc. indicates intermingling of discrete bodies
Suffixes:
a - sapric
b – buried
e – hemic
f – permanently frozen
g -strongly gleyed (low-chr matrix)
i - fibric
jj - cryoturbated
k - carbonate accumulation
m - strong cementation
r - weathered bedrock
s - illuvial sesquioxides
t - illuvial clay
w - color or structural B

Texture
VCOS - very coarse sand
COS – coarse sand
S -sand
FS - fine sand
VFS - very fine sand
LCOS -loamy-coarse sand
LS - loamy sand
LFS - loamy fine sand
COSL - coarse sandy loam
SL -sandy loam
FSL - fine sandy loam
VFSL - very fine sandy loam
L - loam
SI -silt
SIL - silt loam
SCL - sandy clay loam
CL - clay loam
SICL - silty clay loam
SC - sandy clay
SIC - silty clay
C - clay

Coarse fragments
Size classes
Equant shapes (diameter):
2-75 mm - pebbles (gravelly) GR
75-250 mm - cobbles (cobbly) CS
250-600 mm - stones (stoney) ST
>600 mm - boulders (bouldery) BY

Flat (length):
2-150 mm - channers (channery) CH
150-380 mm - flagstones (flaggy) FL
380-600 mm - stones (stoney) ST
>600 mm - boulders (bouldery) BY

Volume classes
<15% - no special modifier
15-35% - add adjective to modify textural term: GR, CS, ST, BY
35-60% - add "very" and adjective to textural term: GRV, CBV, STV, BYV
>60% - add "extremely" and adjective to textural term, such as "extremely gravelly loam": GRX, CBX, STX, BYX
If too little fine earth to determine texture, the coarse fragment term is used alone, "gravel", "cobbles": GR, CO, ST, BY

Mottles (including redox features)
Abundance: F – few, mottles <2% of surface area
C - common, mottles 2-20% of surface area
M - many, mottles >20% of surface area

Size: 1 - fine, <5 mm diameter
2 – medium, 5-15 mm diameter
3 – coarse, >15 mm diameter

Contrast:
F - faint, matrix and mottles differ by no more than 1 unit of chroma or 2 units of value .
D - . distinct, matrix and mottles differ by 2.5 units of hue, or 2-4 units of chroma, or 3-4 units of value
P - prominent, matrix and mottles differ by >2.5 units of hue, or >4 units of chroma or value

Structure
Grade:
0 - structureless
1 - weak, peds barely visible in place, few peds in disturbed sample
2 - moderate, peds easily visible in place, mix of entire peds and unaggregated material in disturbed sample
3 - strong, peds are distinctly visible in place, separate cleanly into whole units when disturbed.

Size

Size class	Granules (dia) Plates (thickns)	Blocks (dia)	Prisms (dia)
VF - very fine	< 1 mm	< 5 mm	< 10 mm
F – fine	1-2 mm	5-10 mm	10-20 mm
M – medium	2-5 mm	10-20 mm	20-50 mm
C –coarse	5-10 mm	20-50 mm	50-100 mm
VC – very coarse	>10mm	>50mm	>100mm

(for plates; "thin" replaces "fine" and "thick" replaces "coarse" in verbal descriptions but not database symbols)

Type
GR - granular, no faces accommodating neighboring peds
PL - platy
PR - prismatic
CPR - columnar, like prismatic but rounded caps,
ABK – angular blocky
SBK - subangular blocky

Consistence
Dry/moist
L/L - loose
S/FR - soft/very friable, easily crushes to powder or single grain
SH/FR - slightly hard/friable, easily broken between thumb and forefinger
MH/FI - moderately hard/friable, crushes under moderate pressure between thumb and forefinger
HA/VFI - hard/very firm, difficult to break between thumb and forefinger
VH/EFI -very hard/extremely firm, cannot be crushed between thumb and forefinger, difficult to break in hands
EH/SR - extremely hard/slightly rigid, cannot be broken in hands but can be underfoot .

Wet
Stickiness
SO - nonsticky, no adherence when pressure is released
SS - slightly sticky, soil adheres to both thumb and finger but comes off cleanly, doesn't stretch
S - sticky, soil stretches somewhat before pulling off of one finger
VS - very sticky, soil adheres to both fingers and stretches

Plasticity
PO - nonplastic, roll (6 mm by 4 cm) won't support its own weight if held on end
PS - slightly plastic, thick roll (6 mm by 4 cm) barely supports its own weight
P - moderately plastic, thin roll (4 mm by 4 cm) supports its own weight
VP -very,plastic, very thin roll (2 mm by 4 cm) supports its own weight

Roots
Abundance
Number per cm^2 (F, VF), 1 dm^2 (M, CO), 1 m^2 (VC)
1 - Few <1
2 - Common, 1-5
3-Many, >5

Size
VF - very fine, <1 mm diameter
F - fine, 1-2 mm diameter
M -medium, 2-5 mm diameter
CO - coarse, 5-10 mm diameter
VC - very coarse, >10 mm diameter

Effervescence of carbonates in 1NHCl; in notes
slightly effervescent, bubbles readily seen
strongly effervescent, bubbles form a low foam
violently effervescent, thick foam forms quickly

Horizon boundary
Distinctness
A - abrupt, <2 cm thick transition zone
C - clear, 2-5 cm
G - gradual, 5-15 cm
D - diffuse, >15 cm

Topography
S - smooth, planar with few irregularities
W - wavy, undulations are wider than they are deep
I - irregular, pockets are deeper than they are wide
B - broken, horizon is discontinuous (parts are unconnected with other parts)

Standard Operating Procedure (SOP) # 5: Plant Cover Measurement

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. General

Cover is measured by the point-intercept method at 100 points, using a laser pointer for vegetation below eye level (Fig. B1) and a periscope-style densitometer for vegetation above eye level. Point intercept measurements are made at 25-cm intervals along the tape, from 0 through 6 m and 10 through 16 m, running the north to south transect first and then the west to east transect. Be careful to run the transects in this order. Place the base of the laser pole next to the mark on the tape with the laser arm perpendicular to the tape. Position the laser so that the laser point falls on the right side of the tape when you are facing down the transect (i.e., facing from north to south or west to east). With our laser holding device (Fig. B1) this results in points about 12 cm from the tape. We record the first (highest) hit by each species at each point and the height class of that hit.

The laser is set on the pole at a convenient height, typically about 1 m. For plants that are above the laser holder, flip the laser over and sight upwards. In tall vegetation or poor lighting conditions where you are uncertain whether the upward-pointing laser has "hit" vegetation or not, use the densitometer (Fig. B2). Remove the laser from the pipe and set the densitometer on top of the pipe where the laser was, level the densitometer, and note if the crosshairs intercept any plants. It may be necessary to move vegetation that is just overhead out of the way to sight higher tiers. Occasionally there will be vegetation in the approximately 15 cm height zone where the laser is. In such cases record the plant if you estimate that it would have been intercepted by a vertical line through the center of the laser.

Species occurring on the plot but not hit by point-intercept sampling are also recorded, after point sampling.

B. Data Recording

For the point-intercept data, a new blank data file is started for each transect. The naming convention is XXXptsTrans#.xls for all files, where XXX is the node abbreviation and # is a sequential number for the transects at a node (note: this number is arbitrary and not tracked in the database or matched between years). The point data itself is recorded on the worksheets “Sheet1”, “Sheet2”, “Sheet3”, etc. sequentially for each plot through the transect. Record the plot number at the top of the form

(“Sheet1” will only correspond to Plot 1 on the first transect of a node), and then move sequentially down the form, making sure that the point identifier matches the tape location being read. The point identifiers are a join of the cardinal direction of the transect segment from plot center (N, S, W, or E), plus the tape measurement for the point location in m.

Data forms have space for 5 plants at each of the 100 points per plot. Anywhere from zero to 5 plants may be recorded at a point, depending on the number of laser hits.

The data recorders are populated with the NPSpecies list of all vascular plants in the park unit (the *V* list); a selected list of 55 nonvascular species, genera, and codes for unknowns (the *N* list); and a list of all vascular genera and families (excluding some small monogeneric families) in the Network plus vascular unknown codes (the *H* list, for “higher taxa”). The user can also populate another list of commonly encountered plants, drawn from the prior lists and called the shortlist (list *S*, found on worksheet “Shortlist”), and a list of unknown plants (the *U* list, found on the “Unknowns” worksheet). When recording a plant name for a point intercept (on “Sheet1” etc), the recorder first chooses a list from the first column (choices *N*, *S*, *U*, and *V*; the default is *S*), and then a plant name from the corresponding dropdown list in the second column. Recording is much easier with a good shortlist, which is populated ahead of time from the *V* and *N* lists. Note that the shortlist remains available for all plots in the file (i.e., all plots on one transect). The *N* list of selected non-vascular plants is also stored as a lookup table in the project database.

C. Height classes

Record one height class (the highest one encountered) for each species at a point. Height classes (the third column) are 0-20, 20-50, 50-100, 100-150, 150-300, and > 300 cm. Move vegetation aside as needed to allow the pointer to hit lower tiers of vegetation. For the height classes below 50 cm, use the sliding scale on the point-intercept pole to judge the height class. For the 100- and 150-cm breaks, use a tape measure to calibrate some point on your body, such as your waist or your chin. To distinguish the 150-300 and >300 cm classes, calibrate your eye with a tape measure.

D. The ground layer

All points should have a ground cover recorded in the row labeled *G* (Table B4). LITTER is dead plant material that is resting on the ground; standing dead plant material (still attached to roots and in life position) is *not* recorded as litter or plant. The ground cover under a continuous moss layer is usually LITTER, because live moss rarely extends down to a mineral substrate. If the point is occupied by a living plant base (most often a shrub or tufted graminoid), record the ground cover as *BasalVeg*. If there is a lichen/algae crust directly on soil, record it as a ground cover of *cryptogammic crust* (and don’t record crustose lichen as a plant). A crustose lichen on a rock or downed wood is recorded as a plant (2LC) over ROCK or WOOD ground cover. Record WATER when water at least 5 cm deep is ponded over the surface. BEDROCK is used if the rock appears to be attached to rock outcrops, as opposed to a loose fragment.

The height column on the G (ground cover) line is used to record the thickness of the lichen mat, rounded to the nearest 5 mm increment. This measurement is made by gently pushing a graduated 3 mm steel rod into the mat. Record this thickness whenever a lichen is intercepted at a point. If no lichens were intercepted, record a thickness of zero; this cell should always have an entry. If a lichen is intercepted on the side of a tussock or other feature such that there is empty space below it, estimate the thickness that would be present of the lichen were laying on a flat ground surface.

Table B4. Ground cover classes for point-intercept sampling

Class	Description
LITTER	Litter and Duff
GRAVEL(2-75)	Gravel (particles 2-75 mm)
ROCK(>75)	Cobbles to boulders (> 75 mm)
SOIL	Bare soil (particles < 2 mm)
ASH	Ash (from forest or tundra fire)
BasalVeg	Basal vegetation
BEDROCK	Bedrock
CryptCrust	Cryptogamic Crust
SNOW	Snow
TEPHRA	Tephra (volcanic ash)
WATER	Water
WOOD	Wood (>75 mm diameter)

Some workers find it helpful to copy a default ground cover in every blank for a given plot. To accomplish this, scroll right to the worksheet labeled “DataTemplate”. In the first blank for groundcover (row 8, column B), select the groundcover you want for the default. Next press the button “CreateForm”. This will ditto your choice down the form. Now select column B, copy it and paste into the sheet where you want the default groundcover to appear. Note: adding a default ground cover can only be done before you start recording data on a plot, because *the paste operation will also overwrite any plants recorded on the form* with blanks.

E. Unknown plants

Collect any vascular plants not identified to the species level or where the species ID is not certain. Collections are recorded on the “Unknown” worksheet, where they are automatically assigned a sequential identification number that starts over at 1 in each data file (i.e., each transect). Fill in a plot number if a collection is made; in certain cases collections may be omitted (see below); *if nothing was collected, omit the collection plot number*. A name for the plant is made using the *H*, *N*, or *V* lists (Higher taxa, nonvascular taxa, or vascular taxa). Name the plant to the lowest taxonomic level possible (e.g., to the genus from the *H* list). After it is entered on the unknowns sheet, the plant will be available to record at points using the *U* list selection. It will also be available at subsequent plots on that transect if it is encountered again. Enter any identifying notes that will help you to track the unknown during point sampling (these notes will appear with the plant name on the choice list). In situations where a specimen is not helpful for identification of an unknown (e.g., only non-descript leaves are available), you may list the plant on the unknowns sheet and write a note “not collected”;

the field name you supply will be the final for this plant. If you see an unknown you recognize from another transect you should normally collect it again. If you are certain it is identical to a previous collection and choose not to collect it again (e.g. if no good specimen is available), refer carefully to that collection in the notes field (give the transect and collection number where it was collected before) and again leave the collection plot field blank.

Collect all the unknowns near to but *outside of the plot*. Collections should be carried in a plastic bag until that evening in camp. In camp the specimens should be pressed and labeled with the node name, plot number, date, sequential unknown number, and name given on the data form.

F. Other Plants

Below the final point on the intercept form is a space for recording plants on the plot that were not hit by points. Record these during a walk-around after finishing the point-intercept sampling but before removing the measuring tapes. Record all nonvascular plants that are included on our sampling list. Record all vascular plants, but to avoid numerous new collections you may omit unknown vascular plants present as just 1 or 2 individuals. (This corresponds to Domin scale of 2 or higher; Kent and Coker 1992.) Spend no more than about 10 minutes searching for other plants. Remember to exclude the area within 2 m of the plot center (Fig. 8). Don’t deliberately record any plants listed previously as hits with point intercept, but also don’t worry if this occurs by accident (the duplicates can be removed later).

G. Notes

Notes about plant phenology, sampling issues, and any features of interest at a plot are made in pencil in a notebook with waterproof paper.

H. Field Daily Backups

Each evening a copy of the file used that day should be made in a folder named for the node and also backed up to a field computer. Name the backup copy XXXptsTrans#Z.xls, where XXX is the node abbreviation, # is the transect number assigned previously, and Z is a month-day code for each day’s backup from a particular transect. For example, if the first day on the Asik node, transect 1, is July 14, a copy of “ASKptsTrans1.xls” is created, named “ASKptsTrans1jul14.xls”, and placed in the ASK folder on the data recorder, while “ASKptsTrans1.xls” is retained in the root “My Documents/Business” folder for additional sampling on the next day of transect 1. When a transect is complete, move both the daily cumulative backup and the last version of the transect’s point file to the folder named for the node on the field computer. If the transect is complete, then at this time the blank template file XXXptsTrans#.xls should be copied and named with the next transect number for the next day’s use.

Standard Operating Procedure (SOP) # 6: Tree measurements
Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. General

We will measure and map the location of all trees (including standing dead trees) over 12 cm diameter at breast height (dbh) within 8 m of the plot center. The dbh of each sapling (1 to 12 cm dbh) is measured for the full plot minus the 2 m-radius central area, but location information is limited to recording the quadrant of each sapling. Seedlings (<1 cm dbh) are counted in four 2 by 2 m microplots.

Trees are recorded in a spreadsheet file named XXXTreesYR.xls, where XXX is the node abbreviation and YR is the year. One file is used for all plots at a node in a season.

B. Trees.

The following data elements are recorded for trees (>12 cm dbh) on worksheet "Trees". For trees with multiple vertical stems at breast height, if any of the stems are >12 cm then all of the data for the tree is recorded here. If all of the stems are <12 cm dbh, then the plant is recorded as a "Sapling" (see below).

Plot: the plot number.
Spec: the tree species. We are using 4-letter abbreviations constructed from the first two letters of the genus and species. If no trees are present, choose "none" and leave the rest of the columns blank. This verifies that data collection was attempted.
CrClass: crown class. Crown classes are defined in Table B5, taken from the Forest Inventory and Analysis National Core Field Guide, Version 6.0 (USFS 2012).
Mort: mortality class. All trees have a mortality class. The classes are Live, Animal (browsing, not insect damage), Disease, Fire, Harvest (or other direct human action), Insect, Unknown, Vegetation (suppression by competition), and Weather.
Az: azimuth. Measure the azimuth (relative to magnetic north) from the plot center to each tree with a compass; if you are sighting from the tree back to plot center be sure to correct for a 180 degree difference.

Dist: distance. Measure distance using an electronic distance measuring device (with target placed at the plot center) or tape measure. Measure distance to the nearest side of the tree in m with 2 decimal places.
DBH: diameter at breast height. Measure (dbh) in cm to 0.1 cm using a diameter tape. Measure at 1.37 m (4.5 feet) above the ground line on the uphill side of the tree. Note a point on your body at this height and use this to position the diameter tape.
CrRad: crown radius. Estimate the crown radius in meters to the nearest 0.1 m using a tape measure. For trees with asymmetrical crowns, estimate an average radius (one that would describe a circle with the same area as the tree crown). All trees have a crown radius entry; dead trees have a crown radius of zero.

For trees with multiple stems at 1.37 m height, measure each stem and enter it on a separate line with the plot, species, and mortality class. Determine the crown class, azimuth, distance, and crown radius for the group of stems as a whole and enter them with the first diameter. For the other stems of that individual, choose "(multistem)" for the crown class and leave azimuth, distance, and crown radius blank for the other stems of that individual.

Table B5. Tree Crown Classes

Choice	ChoiceDescription
Codominant	Trees with crowns at the general level of the crown canopy. Crowns receive full light from above but little direct sunlight penetrates their sides. Usually they have medium-sized crowns and are somewhat crowded from the sides. In stagnated stands, co-dominant trees have small-sized crowns and are crowded on the sides.
Dominant	Trees with crown extending above the general level of the crown canopy and receiving full light from above and partly from the sides. These trees are taller than the average trees in the stand and their crowns are well developed, but they could be somewhat crowded on the sides. Also, trees whose crowns have received full light from above and from all sides during early development and most of their life. Their crown form or shape appears to be free of influence from neighboring trees.
Intermediate	Trees that are shorter than dominants and co-dominant, but their crowns extend into the canopy of co-dominant and dominant trees. They receive little direct light from above and none from the sides. As a result, intermediate trees usually have small crowns and are very crowded from the sides.
Open grown	Trees with crowns that received full light from above and from all sides throughout most of its life, particularly during its early developmental period.
Overtopped	Trees with crowns entirely below the general level of the crown canopy that receive no direct sunlight either from above or the sides.

C. Saplings.

The following data elements are recorded for saplings (1 to 12 cm dbh) on worksheet "Saplings. Only live saplings are measured. A 2 m radius circle at the center of the plot is omitted.

Plot: the plot number.

Quad: quadrant, the "pie slice" of the plot where the sapling is located. A (northeast), B (southeast), C (southwest), D (northwest).
Spec: the tree species. We are using 4-letter abbreviations constructed from the first two letters of the genus and species. If there are no saplings in the quadrant, choose "none" and leave the remaining 3 columns blank; do this for each quadrant.
CrClass: crown class. See above for definitions.
DBH: diameter at breast height. Measure (dbh) in cm to 0.1 cm using a diameter tape or calipers. Measure at 1.37 m (4.5 feet) above the ground line on the uphill side of the tree. Note a point on your body at this height and use this to position the diameter tape or caliper.
CrRad: crown radius. Estimate the crown radius in meters to the nearest 0.1 m using a tape measure. For trees with asymmetrical crowns, estimate an average radius (one that would describe a circle with the same area as the tree crown).

For saplings with multiple stems at 1.37 m height, measure each stem and enter it on a separate line with the plot, quad, and species. Determine the crown class and crown radius for the group of stems as a whole and enter them with the first diameter. For other stems of that individual, choose "(multistem)" for the crown class and leave the crown radius blank. Don't count dead stems of saplings.

D. Seedlings.

Seedlings are counted in four 2 by 2 m microplots. These microplots are placed along the measuring tape used to mark the point intercept transects. The microplots are at the center of each 6-m leg of the transects, i.e., from the 2 to 4 m or the 12 to 14 m marks. There is one microplot in each quadrant of the plot, located on the right side of the tape when viewed from the plot center (i.e., clockwise from the tape; Fig. 8). Microplots are named the same as the quadrants that they fall into, lettered clockwise sequentially around the plot starting with A next to the north transect (Fig. 8). Use a 2 m tape measure to identify samplings that are "in" or "out" of a microplot. The following data elements are recorded for seedlings (less than 1 cm dbh) on the "Seedlings" worksheet.

Plot: the plot number.
Spec: the tree species. We are using 4-letter abbreviations constructed from the first two letters of the genus and species. If there are no seedlings in any of the microplots, enter "none" on the "Seedlings" table and leave the remaining 4 columns blank
CountA, CountB, CountC, CountD: the count of seedlings of the indicated species on the four 2 by 2 m microplots A, B, C, and D. If a species occurs in a microplot and is absent on another, be sure to enter zero under the microplot(s) where it is absent to verify that observations were made.

E. Field Daily Backups

Each evening a backup copy of the tree data file cumulative to that date should be copied to a folder named for the node on the data recorder and a field computer. *These files must be given new names daily to avoid overwriting*. Rename the backup file with the date inserted "XXXTreesDayMonYr.xls"; XXX is the node abbreviation and Day, Mon, and Yr are appropriate for the date. The original file "XXXTreesYr.xls" remains on the data recorder under "My

Documents/Business" and data is added to it each day until the node is completed. Upon completion of the node, move the trees file to the folder named for the node (and to the field laptop) and start a new blank file for the next node.

Standard Operating Procedure (SOP) # 7: Post-field Procedures for Vegetation Nodes

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. General

The data format on the field data recorders maximizes convenience in the field, and the raw field data must be processed before importing into the database. The basic steps are as follows.

A1. Copy the field spreadsheet files from the data recorder to the office computer and make a second copy as a backup.

A2. Prepare the spreadsheet tables for database import.

A3. Import the spreadsheets into temporary tables in a working database. This is currently a Microsoft Access database that is linked to the master database.

A4. Append the data to the master database. This is a Microsoft SQL Server INPYUGAMS08SQL\NUNA, database name ARCN_VegSoils.

A5. To create the Access "front end" working database linked to the master database, do the following. First, copy the following script to a text file and save as "veg_odbc.dsn":

```
[ODBC]
DRIVER=SQL Server Native Client 10.0
UID=DKSwanson
DATABASE=ARCN_VegSoils
WSID=INPYUGA22311
APP=Microsoft Office 2010
Trusted_Connection=Yes
SERVER=INPYUGAMS08SQL\NUNA
```

Now create an Access database and under the "External Data" tab select "ODBC Database". Choose to link to the data source by creating a linked table (do not import the data), and navigate to the "veg_odbc.dsn" file created above and select it, then "OK". Highlight all the "dbo.*" (database objects) plus the tables INFORMATION_SCHEMA_COLUMNS and

INFORMATION_SCHEMA_TABLES. This database now gives you access to the master database while allowing you to store temporary tables and queries.

B. Photography

B1. Download photographs into a folder labeled by the node and year, placed in the photographs folder under the project file on the O (ARCN) drive (O:\Monitoring\Vital Signs\Terrestrial Vegetation and Soils\Photos).

B2. Catalog the photos.

B2.1. The catalog will include columns for the date, time, file size, file name, plot, view, and note. The catalog may be created using specialized photograph catalog software, or using any spreadsheet software as described below. In addition, add the NPS mandatory metadata fields (see section B3 below).

B2.2. To create a photograph spreadsheet, write the contents of the folder containing the photographs to a file and open in spreadsheet software. In the Microsoft Windows environment, this can be accomplished by creating a text file with the following command:

```
dir /n >photolog.txt
```

The file name after the “>” is your option. Save this line of text in a file with *.bat extension, e.g., “filelist.bat” in the folder where the photos are. Next, double-click on the bat file and a directory of the folder will be written to the text file (“photolog.txt”). Open the text file in your text editor, delete all of the lines that do not contain a photograph file names, and save. Import this text file into your spreadsheet as a “Fixed width” text file. Label the columns (date, time, ampm, filesize, filename), add new column headings “plot”, “view”, “note”, and save as tab-delimited text.

B2.3. For plot photography, photographs taken in the proper order may be labeled in batches by copying the following column of cell values into the “view” column:

```
toN
toNE
toE
toSE
toS
toSW
toW
toNW
poleN
poleNE
poleE
poleSE
poleS
poleSW
poleW
poleNW
fromN
```

```
fromE
fromS
fromW
center
soil
```

The “plot” entry for this entire block of photos can be filled with a composite node-plot identifier, e.g., KUZ01 for Kuzitrin Lake node, plot 1. For photos not taken on a plot, the “Plot” column may be left blank and the location described under “View”.

B3. Populate the NPS mandatory photo metadata fields. Add the following columns to your spreadsheet and populate them as indicated.

Title – concatenate Plot, View, and Note
Image_Content_Place – populate this with the WGS84 latitude and longitude, separated by a comma. To accomplish this, you could make a database join with your plot GPS data, though it may be faster simply to copy and paste the values.
NPS_Unit_Alpha_Code – ditto the 4-character park code
Metadata_Access_Constraints – fill this in with the work “public”
Contact_Information – “NPS Fairbanks Alaska administrative center”

B4. Import the data into the database. The text file prepared above is imported into the database and appended onto the table “photos”.

C. Site data

C1. Download all of the daily backup files and the final file containing all of the days’ data for each node from the field data recorders to the appropriate data subfolder under the project folder on the O drive (O:\Monitoring\Vital Signs\Terrestrial Vegetation and Soils\Data, with subfolders for the year and “SoilSite”, e.g. O:\Monitoring\Vital Signs\Terrestrial Vegetation and Soils\Data\2013\SoilSite). Copy the final file containing all of the days’ data for each node into this folder. Create a sub-folder called “Backups” inside of each node file and put all of the field daily backups in it (they will not be used unless problems arise).

C2. Exit the backup folder, then open the file containing all of the data from the node, labeled XXXSiteYR.xls, where “XXX” is the node abbreviation and YR is the year abbreviation. Highlight the data, copy, then paste special (transpose) to a new blank workbook.

C3. In the new (transposed) table, delete lines 2 and 3, which contain only shading and sublist headings. Add columns called “Node” and “SampleYear”, paste the node abbreviation and year to all records, and save as “XXXSiteYRtransposed.xls”, i.e. the same name as the original but with “transposed” added to the name.

C4. Scan the soil-site data for missing values and obvious problems. Missing data for “Frzn” and “Holdep” can usually be obtained from the paper soil description forms.

C5. Import the transposed data into Access as the table ImportXXXsiteYR. All the number fields should be important as integers, and the DateTime is imported as text.

C6. Append the data to the "Plot" master table in the SQL Server database. All column labels from the imported spreadsheet should match their corresponding columns in the database, except the "Veg1%" and "Veg2%" columns on the spreadsheet map to fields "Veg1pct" and "Veg2pct" in the database. The "%" abbreviations are convenient on the small data recorder screens, but can cause problems in database operations because the "%" can be interpreted as a wildcard character.

D. Cover Data

D1. Download all the individual days' point intercept files from the data recorder to a single data subfolder under the project folder on the O drive. Make subfolder called "Backups" under each node and put backup copies of all the files in it before beginning processing.

D2. The point-intercept data is saved in a long table that is formatted for convenient entry. This data entry form is *not* an automated form that writes automatically to a database table. The data must be processed by a macro that scans through the data and writes it to output tables in proper format. To do this, open each point data file in SpreadCE and run the "ConvertData" macro (ctrl-m). The macro creates 2 new sheets, one called "ConvertedPlants" and the other "ConvertedGround" containing all the data in the file. Next run the "OtherPlants" macro (ctrl-t) to merge all of the "Other Plants" lists (plants found during the walk-around after point intercept sampling) into a new sheet called "OtherPlants". Copies of these macros are provided in Tables B6 and B7.

D3. Merge the data from the "ConvertedPlants" tables from the files for individual transects at a node into one table and do the same for the "OtherPlants", "ConvertedGround", and "Unknowns" tables. This may be done by importing the table for each transect of the node into Access and using a union query to merge them. Importing each table individually using the menus can be tedious. The Visual Basic command "DoCmd.TransferSpreadsheet" can be used to automate this. Below is example code for the import of the four worksheets from a file called "WASPtsTrans1converted.xls". In Access, open the Visual Basic Editor and copy this code into a blank window. First edit the path (under the comment 'Set the variables that don't change during a given year) and then edit two statements under the comment "'Set the variables that change". Run using the Run menu or the green triangle arrow and the four tables from the transect should appear in the database. Edit the statements under the comment "Set the variables that change" and run repeatedly to import data from multiple spreadsheets.

```
Private Sub cmdImportExcelSpreadsheet_Click()
    Dim strImportPath1 As String  'the part of the import path that
doesn't change
    Dim strImportPath2 As String  'the part of the import path that
changes
    Dim strImportFileName As String  'the file name minus the .xls
extension
    Dim strWorksheet1 As String
    Dim strWorksheet2 As String
```

```
    Dim strWorksheet3 As String
    Dim strWorksheet4 As String

    'Set the variables that don't change during a given year
    strImportPath1 = "O:\Monitoring\Vital Signs\Terrestrial Vegetation
and Soils\Data\2012\Points\"
    strWorksheet1 = "ConvertedPlants"
    strWorksheet2 = "ConvertedGround"
    strWorksheet3 = "OtherPlants"
    strWorksheet4 = "Unknowns"

    'Set the variables that change
    strImportPath2 = "WAS\"
    strImportFileName = "WASPtsTrans1converted"

    'Run the import
    DoCmd.TransferSpreadsheet acImport, acSpreadsheetTypeExcel12,
strImportFileName & strWorksheet1, strImportPath1 & strImportPath2 &
strImportFileName & ".xls", True, strWorksheet1 & "!"
    DoCmd.TransferSpreadsheet acImport, acSpreadsheetTypeExcel12,
strImportFileName & strWorksheet2, strImportPath1 & strImportPath2 &
strImportFileName & ".xls", True, strWorksheet2 & "!"
    DoCmd.TransferSpreadsheet acImport, acSpreadsheetTypeExcel12,
strImportFileName & strWorksheet3, strImportPath1 & strImportPath2 &
strImportFileName & ".xls", True, strWorksheet3 & "!"
    DoCmd.TransferSpreadsheet acImport, acSpreadsheetTypeExcel12,
strImportFileName & strWorksheet4, strImportPath1 & strImportPath2 &
strImportFileName & ".xls", True, strWorksheet4 & "!"

End Sub
```

After the tables have been imported, they are joined using a Union Query. Below is an example of a Union Query: if the point data for plants for 3 transects in the ASK node have been imported as ASKConvertedPlants1, -2, and -3, the following query will merge them into one table, add the Node symbol ("ASK") and the sample year (2011), and write the result to ASKConvertedPlantsAll:

```
SELECT tmp.* INTO ASKConvertedPlantsAll FROM
(SELECT "ASK" AS NODE, 2011 AS SampleYear, * FROM ASKConvertedPlants1
UNION ALL
SELECT "ASK" AS NODE, 2011 AS SampleYear, * FROM ASKConvertedPlants2
UNION ALL
SELECT "ASK" AS NODE, 2011 AS SampleYear, * FROM ASKConvertedPlants3)
AS tmp;
```

Repeat for the "ConvertedGround", "OtherPlants", and "Unknowns" data.

<u>D4</u>. Perform some basic edit checks on the point data. (1) The merged "ConvertedGround" file will have numerous empty records from the extra sheets with no data. These will have plot number 0 and may be selected using this criterion and deleted. Check to be sure that the "0" plot records really are

empty (and not just missing the plot number) before deleting. (2) The merged "Unknowns" file will have numerous empty records, because Access will import all of the blanks on the form, filled or not. Sort the merged :"Unknowns" table by "Unknown_Name" and delete all of the empty records. (3) Check for points where no ground cover data was entered. You may cautiously fill in the missing data where it is obvious what the entry should be. For example, the most common missing ground cover is LITTER on plots where a moss layer is present that consists of a mat-forming species such as *Sphagnum* or *Hylocomium splendens* that produces a litter layer. In such a case we could confidently fill in the missing ground cover as LITTER. If there is any doubt fill in the symbol NODATA. (4) Missing lichen mat thickness. Sometimes when there is no lichen layer the worker forgets to record a zero for the thickness. For points with no lichen hit and missing lichen thickness, fill in a zero for height. (5) Missing height classes for point-intercept plants. These can occasionally be fixed for plants known to always be less than 20 cm tall. For example, a hit on a ground-dwelling moss or lichen can nearly always be assigned to the 0_20 class. In other cases fill in NODATA for the height class.

<u>D5</u>. Append the "ConvertedPlants", "ConvertedGround", "OtherPlants", and "Unknowns" data for each node to the master (SQL Server) database tables. The data from "ConvertedPlants" goes into the database table "PointPlant", and the data from the "ConvertedGround" sheets goes into the database table "PointGround"; the "OtherPlants" and "Unknowns" data go into the tables of the same name. The plant names recorded in the field go into the database column named "FieldItem" in "PointPlant" and "OtherPlant", which includes both accepted plant names (for plants known in the field) and temporary codes for unknowns that will be converted later. In the "Unknowns" database table, the name assigned to the plant in the field goes into the column "CollectionNameField" and the field column "Gr" (plant menu group) is not appended.

<u>D6</u>. Populate the "Node" table's memo fields where you may describe the access, campsite, and data quality issues for the node to make future sampling and data analysis easier.

<u>D7</u>. Populate the "Transect" table. Fill in the informal transect name to each set of plots that constitutes a single transect of systematically spaced plots (this name was usually coined during fieldwork planning). Fill out the memo field "TransectAccess" to describe access to the transect from the campsite and the memo field "TransectNarrative" to highlight ecological features of the transect and plots within it. Include field notes if any were taken. Also, populate the column "TransectName" in the "Plot" table with the same names used in the "transect" table to facilitate joins.

<u>D8</u>. When unknown plant identifications become available, enter them into the "CollectionNameFinal" column in the Unknowns table. Use the choice list drawn from NPSpecies for the Park unit involved (the same list as was used for the data recorder in the field). Then the final names can be associated with the individual point hits and entered into the PointPlant and OtherPlant tables in Access using an update query. The names in the "FieldItem" column of PointPlant and OtherPlant remain unchanged, preserving the original field data, while the updated name will be joined to each record. The field used to create this join requires a little work to prepare. The join will be based on the sequential unknown number assigned to each unknown plant starting from 1 each day, and the name of the transect's point-intercept data file where the unknown was recorded. These

two fields are already present in the “Unknowns” table. In the PointPlant and OtherPlant tables, the sequential unknown number is extracted from the long FieldItem string with the following update query:

```
UPDATE PointPlant SET PointPlant.CollectionNumber =
Left([FieldItem],InStr([FieldItem],",")-1)
WHERE (((PointPlant.CollectionNumber) Is Null) AND
((InStr([fielditem],","))>"0"));
```

This query extracts all of the text up to the first comma in “FieldItem” and writes it to the “CollectionNumber” field; it operates only on records where a comma was located, i.e., the unknowns. Note: to perform this operation on the OtherPlants table, the query must be modified so that the UPDATE and SET commands are followed by “OtherPlant” rather than “PointPlant”.

Once “CollectionNumber” has been populated, the PointPlant and OtherPlant tables can be joined to the Unknowns tables on the common fields for CollectionNumber and SourceFile, to obtain the correct name for the plant. This join is accomplished using the master database objects (“views” i.e. queries) “OtherPlantFinal” and “PointPlantFinal”.

Table B6. Convert Point Intercept Data macro[1]

	A	B	C	D	E
56		=ECHO(FALSE)			
57		=WORKBOOK.INSERT(1)			Insert and name destination sheet for plants
58		=WORKBOOK.NAME("Sheet7","ConvertedPlants")			
59		=WORKBOOK.INSERT(1)			Insert and name destination sheet for ground cover
60		=WORKBOOK.NAME("Sheet7","ConvertedGround")			
61		=SET.VALUE(D61,1)		1	sheet number
62		=SET.VALUE(D62,2)		2	Row counter for output in plants table
63		=SET.VALUE(D63,2)		2	Row counter for output in ground table
64		=WHILE(D61<7)			iterate through the sheets
65		=SET.VALUE(D65,"Sheet"&D61)		Sheet1	sheet name
66		=SET.VALUE(D66,D65&"!C1")		Sheet1!C1	Reference to plot number
67		=SET.VALUE(D67,INDIRECT(D66))		0	Plot number
68		=SET.VALUE(D68,2)		2	Row counter for point ID
69		=WHILE(D68<702)			End of input table is row 702
70		=SET.VALUE(D70,D65&"!C"&D68)		Sheet1!C2	Reference to point
71		=SET.VALUE(D71,INDIRECT(D70))		E16.0	Point ID
72		=SET.VALUE(D72,1)		1	Counter for inner loop of 6
73		=WHILE(D72<6)			File through the plant rows only here
74		=SET.VALUE(D74,D68+D72)		3	Row counter for inner loop that reads data
75		=SET.VALUE(D75,D65&"!B"&D74)		Sheet1!B3	Reference to the name cell
76		=SET.VALUE(D76,D65&"!C"&D74)		Sheet1!C3	Reference to the height cell
77		0			Copy data only if there is an entry
78		=FORMULA(D67,INDIRECT(ADDRESS(D62,1,,,"ConvertedPlants")))			write the plot number

	A	B	C	D	E
79		=FORMULA(D71,INDIRECT(ADDRESS(D62,2,,,"ConvertedPlants")))			write the point ID
80		=FORMULA(INDIRECT(D75),INDIRECT(ADDRESS(D62,3,,,"ConvertedPlants")))			copy over the plant name
81		=FORMULA(INDIRECT(D76),INDIRECT(ADDRESS(D62,4,,,"ConvertedPlants")))			copy over the height class
82		=FORMULA(GET.WORKBOOK(16),INDIRECT(ADDRESS(D62,5,,,"ConvertedPlants")))			writes the source filename, to allow link to unknowns table
83		=SET.VALUE(D62,D62+1)			Increment output row if data was written
84		=END.IF()			
85		=SET.VALUE(D72,D72+1)			Increment the inner loop
86		=NEXT()			
87		=SET.VALUE(D74,D68+D72)			Move on to ground cover row
88		=SET.VALUE(D75,D65&"!B"&D74)			Reference to ground cover type
89		=SET.VALUE(D76,D65&"!C"&D74)			Reference to nonvasc thickness
90		=FORMULA(D67,INDIRECT(ADDRESS(D63,1,,,"ConvertedGround")))			write the plot number to the ground sheet
91		=FORMULA(D71,INDIRECT(ADDRESS(D63,2,,,"ConvertedGround")))			write the point number to the ground sheet
92		=FORMULA(INDIRECT(D75),INDIRECT(ADDRESS(D63,3,,,"ConvertedGround")))			copy over the ground cover name
93		=FORMULA(INDIRECT(D76),INDIRECT(ADDRESS(D63,4,,,"ConvertedGround")))			copy over the nonvasc height
94		=SET.VALUE(D63,D63+1)			Increment output row
95		=SET.VALUE(D68,D68+7)			Advance to the next point
96		=SET.VALUE(D74,D68)			Reset data row number to next point
97		=NEXT()			
98		=SET.VALUE(D61,D61+1)			Advance to next sheet
99		=NEXT()			
100		=FORMULA.ARRAY(GET.WORKBOOK(16),Unknowns!F2:F201)			This line adds the filename to the unknowns list for export
101		=RETURN()			

[1] This macro is in the old Microsoft Excel 4.0 macro format, which runs in SpreadCE software. It is stored in a special macro sheet. Variables are stored in cells on this sheet, in this case column D. Cell references depend on the macro's position with the column letters and row numbers indicated.

Table B7. Convert other plant data macro[1]

	A	B	C	D
106	=ECHO(FALSE)			
107	=WORKBOOK.INSERT(1)			Insert and name destination sheet for plants
108	=WORKBOOK.NAME("Sheet7","OtherPlants")			
109	=FORMULA("Plot",INDIRECT(D109))		OtherPlants!A1	Write column headings in destination sheet
110	=FORMULA("FieldItem",INDIRECT(D110))		OtherPlants!B1	
111	=FORMULA("CoverClass",INDIRECT(D111))		OtherPlants!C1	
112	=FORMULA("SourceFile",INDIRECT(D112))		OtherPlants!D1	
113	=SET.VALUE(D113,1)		7	input sheet number
114	=SET.VALUE(D114,2)		135	Row counter for output table
115	=WHILE(D113<7)			iterate through the sheets
116	=SET.VALUE(D116,"Sheet"&D113)		Sheet6	input sheet name
117	=SET.VALUE(D117,D116&"!C1")		Sheet6!C1	Reference to input plot number
118	=SET.VALUE(D118,706)		746	Row counter for input plant data
119	=WHILE(D118<746)		746	End of input table is row 745
120	=SET.VALUE(D120,D116&"!B"&D118)		Sheet6!B745	Reference to input plant cell
121	=SET.VALUE(D121,D116&"!C"&D118)		Sheet6!C745	Reference to input cover cell
122	=IF(NOT(ISBLANK(INDIRECT(D120))))			Copy data only if there is an entry
123	=FORMULA(INDIRECT(D117),INDIRECT(ADDRESS(D114,1,,,"OtherPlants")))			write the plot number
124	=FORMULA(INDIRECT(D120),INDIRECT(ADDRESS(D114,2,,,"OtherPlants")))			copy over the plant name
125	=FORMULA(INDIRECT(D121),INDIRECT(ADDRESS(D114,3,,,"OtherPlants")))			copy plant cover class
126	=FORMULA(GET.WORKBOOK(16),INDIRECT(ADDRESS(D114,4,,,"OtherPlants")))			writes the source filename, to allow link to unknowns table
127	=SET.VALUE(D114,D114+1)			Increment output row if data was written

	A	B	C	D
128	=END.IF()			
129	=SET.VALUE(D118,D118+1)			Increment input row
130	=NEXT()			next input row
131	=SET.VALUE(D113,D113+1)			Advance to next sheet
132	=NEXT()			next sheet
133	=RETURN()			

[1] This macro is in the old Microsoft Excel 4.0 macro format, which runs in SpreadCE software. It is stored in a special macro sheet. Variables are stored in cells on this sheet, in this case column D. Cell references depend on the macro's position with the column letters and row numbers indicated.

E. Tree Data

E1. Preprocess tree data in the spreadsheet. Save a copy of each spreadsheet table of tree data into a new file called *processed.xls to avoid overwriting field data. Add the columns Node and SampleYear to each table and populate with the appropriate values. Add a column to the left of "Species" in the Trees and Sampling tables and name it "Treenum". Populate it with a number that is unique for each tree but constant for stems in a multistemmed tree. To do this automatically, on the "Trees" worksheet type "1" in the first line of data under Treenum (cell B2), and in the 2nd line of data under "Treenum" (cell B3) type the formula "`=IF(D3 = "(multistem)", B2, B2+1)`", then ditto the formula down to the end of the table. On the "Saplings" worksheet the new column and formula is similar except shifted one column to the right: put a new column heading "TreeSaplingNum" in cell C1, type "1" in cell C2, and the formula in C3 is "`=IF(E3 = "(multistem)", C2, C2+1)`".

E2. Import into new temporary database tables. Import each spreadsheet table of tree data (Trees, Saplings, Seedlings) into a separate temporary table in the database. Import the number fields SampleYear, Plot, Treenum, Azimuth, and seedling counts as integers, and import all the other number fields as double-precision numbers. Use a union query to merge all the Trees tables from the various nodes into one, and do the same for the Saplings and Seedlings tables. These tables are referred to below as "temporary (new)" tables.

E3. Append seedlings data onto permanent database table. The Seedlings table can be appended directly into the matching columns in the TreeSeedlings table in the database, using an append query.

E4. Append tree data to the master tree database tables. The Tree data in the temporary (new) table contains data that will be divided among two related tables, Trees and TreeDBH, This is done because the field data table actually contains two levels of data, some which (DBH, Mort) is unique to each stem in a multistemmed tree (and thus goes into the TreeDBH master table) and the rest that applies to all stems in a multistemmed tree (and goes in the Trees master table). Using an append query, append the data from the temporary (new) tree data table (step E2 above), columns Node, SampleYear, Treenum, Mort, and DBH to the corresponding columns in the Trees database table. Next create a select query drawing from the temporary tree data table containing the columns Node, SampleYear, Plot Treenum, Spec, CrClass, Az, Dist, and CrRad. Add a select criterion (a WHERE clause) "`CrClass <> "multistem`"). This will give you a table with one record per tree with no nulls in columns Az, Dist, and CrRad (these fields are blank for the extra stems). Append the resulting data to the corresponding columns in the Trees database table.

E5. Append sapling data to the master sapling database tables. The procedure for saplings is similar to that of trees in step E4 above. Sapling data is split into the two related tables TreeSaplings and TreeSaplingDBH. Create a query to append data from the temporary (new) sapling table (step E2 above), columns Node, SampleYear, TreeSaplingNum, DBH to the master database table "TreeSaplingDBH". Next create a select query drawing from the temporary sapling data table and containing the columns Node, SampleYear, Plot, Quad, TreeSaplingNum, Spec, CrClass CrRad. Add a select criterion (a WHERE clause) "`CrClass <> "multistem`"). This will give you a table with one record per tree with no nulls in column CrRad (this field is blank for the extra stems). Append the resulting data to the corresponding columns in the TreesSaplings database table.

F. Soil Horizon Data

F1. This data is entered into a spreadsheet from paper field forms. The typist should have a copy of the data codes used (Fig. B7). Enter all letters in upper case except the horizon designations, which are a mix of upper and lowercase. Create columns named “Node”, “SampleYear”, and “Plot” and ditto this information down on each record as needed (the plot number is available as header information above each soil description on the field forms).

F2. Import into Access and append onto the master table SoilHoriz. Note that columns identifying the date and soil sampler are not appended (they are already in the Site table). All column names on the field form should match the corresponding database fields, except for %GR, %CB, and %ST, which lack the “%” character in the database to avoid problems with interpretation of “%” as a wildcard character. All fields are imported as text except SAMPLEYEAR, PLOT, UPDEP, LOWDEP, GR, CB, and ST (integers) and pH (double-precision number).

G. Recreational grade GPS data

Garmin GPS waypoints are currently downloaded using the State of Minnesota DNR software package called “DNRGarmin”, which is available from http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html.

After downloading and installing this software, launch it and choose the menu option GPS, Set Port, and be sure that USB is checked. Plug the GPS to your computer using a USB cable and turn on the GPS. To connect with the GPS, choose the menu option GPS, Auto Connect to GPS. After working for a few seconds the box in the lower left-hand corner of the menu should read “Connected”.

Next choose menu option Waypoint, Download. A list of the stored waypoints on the GPS will appear. Next choose File, Save To, File. A dialog box appears where you set the filename, path, and file format. Choose the default text file output. Note that the default *.txt format gives you comma-delimited text.

Import the text file containing the waypoints into the database as a temporary table and then use an update query to add the coordinates the master “GPS” table. Note that the date and time information appears in the waypoint file as a single string under the field “comment”; import it is as text rather than a date/time field. You will have to add and populate columns in the temporary Access table called Node (text), SampleYear (number, integer), and Plot (number, integer) to the temporary waypoints table to facilitate the join and update into the master database. The waypoint names that you saved in the field (listed under the column “ident”) should contain the necessary information to populate these plot identifier fields. Append these 3 columns to columns of the same name in the “GPS” table, plus append the following other columns: “lat”, to “GPSrecDD83lat”, “long”, to “GPStrmDD84lon”, “comment” to “GPSrecDateTime”, “altitude” to “GPSrecZ”, and “model” to “GPSrecModel”.

H. Trimble GPS data

H1. Upon return from the field, download the daily GPS data files from the GPS to the project folder on the O: drive (O:\Monitoring\Vital Signs\Terrestrial Vegetation and Soils\Data*YEAR*\GPS\Trimble). Connect the GPS to the computer, start GPS Pathfinder Office software, and follow the most recent instructions provided by the NPS GPS Coordination Program NPS Alaska Region office. When you are done, there should be one file from each day, labeled "RmmddxxA.SSF", where mmdd is the month-date.

H2. Differential correction. Perform a differential correction of the GPS data with GPS Pathfinder Office, following the most recent instructions provided by the NPS GPS Coordination Program NPS Alaska Region office. As of 2013 we had processed all data with the "Use reference position from base provider" option in Pathfinder Office. This position is in ITRF coordinates, which are very close to WGS 1984 and yield positions after differential correction that are also very close to the WGS 1984 system used by GPS. These coordinates thus can be stored and then re-loaded directly back into the GPS to relocate plots.

H3. Export the data to text files. Export the uncorrected coordinates (from the *.SSF files) and the differentially corrected coordinates (from the *.cor files) to text files. In Trimble GPS Pathfinder Office, set the export settings as follows:

H3.1. Load the files to export (File, Open). This will be either all of the uncorrected *.SSF *or* all of the corrected *.cor files.

H3.2. Choose Utilities, Export. The Export dialog box appears.

H3.3. Choose the proper output folder (e.g., O:\Monitoring\Vital Signs\Terrestrial Vegetation and Soils\Data*YEAR*\GPS\Trimble\Export\Corrected). In the Export folder of your Pathfinder Office project, set up subfolders for "Corrected" and "Uncorrected" data and choose the one that matches the data you just loaded.

H3.4. Choose "Sample Generic Database Setup" as your export setup. This produces a comma-delimited text file called "Plot.pnt".

H3.5. Click on "Properties" and leave all at the defaults except for the Attributes. Here check Receiver Type, Date Recorded, Time Recorded, Vertical Precision, and Horizontal Precision. To export the uncorrected values, you must also be sure that under the "Position Filter" tab the "Uncorrected" box is checked under "Include Positions That Are". Then click OK in the Properties dialog box and OK again in the Export dialog box. The "GIS Coordinate System" should default to Lat/Long WGS 1984.

H3.6. Open the *differentially corrected* export file in a text editor and paste the following first line of column headers, and rename the resulting file with a *.csv extension:

```
"record","GPScorDD84lon","GPScorDD84lat","hae","easting","northing","GP
ScorZ","descr","GPStrmModel","GPStrmDate","GPStrmTime","GPScorVertPrec"
,"GPScorHorzPrec"
```

H3.7. Open the *uncorrected* export file in a text editor, past the following first line of column headers, and rename the resulting file with a *.csv extension:

```
"record","GPStrmDD84lon","GPStrmDD84lat","hae","easting","northing","GP
StrmZ","descr","GPStrmModel","GPStrmDate","GPStrmTime","GPStrmVertPrec"
,"GPStrmHorzPrec"
```

<u>H4</u>. Append to the database.

H4.1. Import the two text files to temporary database tables in Access. Name them with "tmp" somewhere in the name so they won't be confused with other tables when the time comes to delete them. Also be sure to flag the file names as corrected and uncorrected. In the import dialog boxes note that the data are Comma-delimited, the first row contains field names, and the text qualifier is a double quote character. Define the field types as indicated in Table B8.

Table B8. Fields for import of Trimble GPS data

Field Name	Data Type	Note
`record`	Long Integer	Sequential number for the record, not appended to the database
`GPScorDD84lon or GPStrmDD84lon`	Double	Longitude; name depends on the origin – corrected (cor) or uncorrected (trm) data
`GPScorDD84lat or GPStrmDD84lat`	Double	Latitude
`hae`	Choose "Do not import field (Skip)"	Height above the ellipsoid, not appended to the database.
`easting`	Choose "Do not import field (Skip)"	Should be blank; not appended to the database.
`northing`	Choose "Do not import field (Skip)"	Should be blank; not appended to the database.
`GPScorZ or GPStrmZ`	Double	This is the elevation in meters relative to mean sea level.
`descr`	Text	This is your field name for the point, used to assign a plot number but not appended to the database
`GPStrmModel`	Text	GPS receiver type
`GPStrmDate`	Text	GPS date
`GPStrmTime`	Text	GPS time
`GPScorVertPrec or GPStrmVertPrec`	Double	Vertical precision in meters
`GPScorHorzPrec or GPStrmHorzPrec`	Double	Horizontal precision in meters

H4.2. Add the key (plot identifier) fields to the temporary tables. Add and populate columns called Node (text), SampleYear (integer), and Plot (integer) to the temporary tables to facilitate table joins. The plot identifiers that you saved in the field should contain the necessary information to populate these plot identifier fields.

H4.3. Run update queries to add the data from the temporary table of corrected GPS data to the "GPS" database table. (Records for Node, SampleYear, and Plot should already be present from appending the recreational-grade GPS data above. If not, append one of the "corrected" temporary tables to create the records and use an update query to fill the remaining columns. The columns on the temporary tables should match their destination columns. Note that GPStrmModel, GPStrmDate, and GPStrmTime are duplicated on the corrected and uncorrected tables and need only be added once.

H4.4. Cross-check the various GPS values. Compute the differences between the 3 GPS values for each plot. The differences should be similar to the expected accuracy of the units used. For latitude, 10^{-5} degrees is approximately 1.1 m, for longitude, 10^{-5} degrees ranges from about 0.47 m at 65° north to about 0.40 m at 69° north.

I. Magnetic declination

Transect azimuths are aligned with cardinal directions from magnetic north. For the first cycle of sampling we used the National Geophysical Data Center (NGDC) Geomag 7.0 model to compute the magnetic declination (http://www.ngdc.noaa.gov/geomag/models.shtml).

<u>I1</u>. Download the model from http://www.ngdc.noaa.gov/geomag/models.shtml and unzip. The model is an executable file run at the command prompt.

<u>I2</u>. Create the input file. The following query extracts the necessary data from the database and formats it for the Geomag model.

```
SELECT Year([datetimeconverted]) & "," & Month([datetimeconverted]) &
"," & Day([datetimeconverted]) AS dateinfo, "D" AS coordinate, "M" &
Round([elev],2) AS elevation, Round([lat],2) AS latitude,
Round([lon],2) AS longitude
FROM (dbo_GPS INNER JOIN dbo_Plot ON (dbo_GPS.Node = dbo_Plot.Node) AND
(dbo_GPS.SampleYear = dbo_Plot.SampleYear) AND (dbo_GPS.Plot =
dbo_Plot.Plot)) INNER JOIN dbo_GPSsummary ON (dbo_Plot.Plot =
dbo_GPSsummary.Plot) AND (dbo_Plot.Node = dbo_GPSsummary.Node);
```

Run, and copy the resulting table into a text file. Using a text editor, replace all tab characters with a space. Name the file "infile.txt" and place it in the same directory as the executable file obtained above from NGDC "geomag70.exe".

<u>I3</u>. Run the geomag model. In the same directory, create a text file called "rungeomag.bat" or similar and place in it this command:

```
geomag70.exe IGRF11.COF f infile.txt outfile.txt
```

Run this bat file and open "outfile.txt" in a text editor. Run find/replace multiple times replacing two spaces with one until the file is character-delimited with a single space.

<u>I4</u>. Import declination onto a temporary table in the database. Import the text file created in the previous step as a temporary table into the database and call it "tmp_declination" or similar. Unfortunately, this file has no plot-identifying information. Go back to the query above, add "Node"

to the selection, and GROUP BY all the fields to remove duplicates and save as "decl_calc" or similar.

Now join this query, including the "Node" column, to your model output table using the date, elevation, latitude, and longitude as join fields. For our purposes, a single correction for declination at each Node is sufficient. So we will compute a mean declination for each node from the model output. The model output for declination has text in it (e.g., "14d" and "3m" for 14 degrees and 3 minutes), so we have to do some manipulation before we can compute a mean.

```
SELECT decl_calc.Node,
Round(Avg(Left([D_deg],Len([D_deg])-1)+(Left([D_min],Len([D_min])-
1)/60)),1) AS AvgD_deg,
round(Avg(tmp_declination.dD_min/60),2) AS AvgdD_deg
FROM tmp_declination INNER JOIN decl_calc
ON (tmp_declination.Longitude = decl_calc.lon)
AND (tmp_declination.Latitude = decl_calc.lat)
AND (tmp_declination.Altitude = decl_calc.elev)
AND (tmp_declination.Date = decl_calc.dateinfo)
GROUP BY decl_calc.Node;
```

This gives an average declination for each node, and the annual change. This data from the initial sample event was appended to the "Node" table so that the true north azimuths of the transects can be determined. In the future we do not need to update this information, but we will repeat computation of declination with new dates in the future to develop a correction factor for declination change to use in locating transects in the field (see SOPs #1 and #2). At the present time the rate of change is about -3° per decade.

J. Notes

Notes about the node, transect, and plots from waterproof field notebooks and in the margins of the soil forms are typed into the database. Enter notes into the database table and column where they are most appropriate (Table B9). Any useful information that field workers recall after the season may be entered from memory. A data entry form that provides a large text box to view the entire note is convenient for this purpose.

Table B9. Database table and columns containing notes from field notebooks or memory

Table Name	Column Name	Column Description
Node	NodeAccess	Description of access issues for the node, i.e. travel between Fairbanks and the node campsite
Node	NodeCampsite	Description of the campsite at the node
Node	NodeNarrative	Notes on data quality issues, days required to complete sampling, etc.
Plot	PlotNote	Notes about the plot, including observations of interest and any sampling mistakes or problems encountered
Plot	SoilNote	Notes about the soil profile
Transect	TransectAccess	Description of access issues for the transect, i.e. travel between the campsite and the plots
Transect	TransectNarrative	Notes on data quality issues, the natural history of the plots, etc.

Standard Operating Procedure (SOP) # 8: Data Analysis and Reporting

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. Individual plot summaries. Some common summaries at the plot level are available in the database as views. These include:

dbo.PlantCoverSummary - the percent cover of each plant on each plot, computed from the point-intercept data

dbo.GroundCoverSummary – the percent cover of each ground cover type on each plot, computed from the point-intercept data

dbo.BasalAreaSummary – the tree basal area, in meters squared per hectare, for each species by plot, separately for saplings (dbh <= 12 cm) and trees (dbh > 12 cm). To get the total basal area of both size classes, create a query without the "sizeclass" column, group by the other columns except "bamsqha", for which you compute the sum.

dbo.SeedlingSummary – the count of seedlings per hectare by species, computed from the counts on the the four microplots.

These plot-level summaries can in turn be summarized informally for groups such as ecotypes or along gradients such as elevation. These summaries should be treated with caution because they have not been corrected for the effect of clustering or selection bias. The more complicated procedure for this correction is described in the next section.

B. Post-strata summaries and change detection

Because of our non-probabilistic sampling scheme, individual plot values are weighted using know proportions of post-strata (ecotypes) and tests are computed with software that can account for the effect of sample clusters (transects). We can apply these techniques to data from a single visit (e.g., the cover of a plant) or data on the change in some quantity between two visits. Change detection will usually involve computing the difference in some plot-level summary of plant cover, tree basal area, etc. between two visit dates and testing whether the change is significantly different from zero.

B1. Select plants. Prior to running a statistical test we need to select the data for a particular plant or group of plants. If a group of plants is involved there will be a select query like this:

```
SELECT Node, SampleYear, Plot,Plant,CoverPct
FROM dbo_PlantCoverSummary
WHERE Plant Like "Dryas*";
```

This example query returns records with all members of the *Dryas* genus. The "Like" statement could be more complex if we are grouping several plants. We then need to sum the cover for all of these plants on each plot. If the first query is saved as "t1" then the second query would be:

```
SELECT Node, SampleYear, Plot, Sum(CoverPct) AS Value
FROM t1
GROUP BY Node, SampleYear, Plot;
```

Since we left "Plant" out of this query, the various species of Dryas on the plot will be summed under the column "Value". Note: if the plants we are aggregating could occur together on a single sample *point* (because of overlapping canopies), a simple sum of the covers of the constituent plants might not be appropriate. If so, go back to the raw point data in dbo_PointPlantRename, select the plants of interest into a table, then from these results run another query with a clause "GROUP BY Node, SampleYear, Plot, Point" to get just one record for each point that has any of the selected plants. Then use a third query to GROUP BY Node, SampleYear, Plot and compute the count of "Point" to get the percent of points that have *any* of the chosen plants.

B2. Difference computation. The previous step produces a table with all the data from all available years. Our sampling occurs over a period of a few years, which we call a *cycle*, separated by a long period without sampling. The cycle of each sample year is stored in the "SampleCycle" table. We need to compute the difference between the two cycles for the plant data from the previous step, including the plots where the plant of interest had zero cover during the first or second cycle. To accomplish this we first select the first sampling cycle ("Cycle = 1" in this case), and then by means of a LEFT JOIN get all the plots sampled in that cycle. The "Nz(Value,0)" function writes a zero for all the plots where the plant was not observed. Note: the "Nz" function is available in MS Access; in SQL Server use "IFNULL" instead. Save the result as "t3".

```
SELECT dbo_SamplingCycle.Cycle, dbo_SamplingCycle.SampleYear,
dbo_Plot.Node, dbo_Plot.Plot, Nz(t2.Value,0) AS ValueNz
FROM (dbo_SamplingCycle INNER JOIN dbo_Plot ON
dbo_SamplingCycle.SampleYear = dbo_Plot.SampleYear)
LEFT JOIN t2 ON (dbo_Plot.Plot = t2.Plot) AND (dbo_Plot.SampleYear =
t2.SampleYear) AND (dbo_Plot.Node = t2.Node)
WHERE dbo_SamplingCycle.Cycle=1;
```

If you are summarizing one year of data you can move on to the next section. To continue with multi-year change, create another query just like the one above, except in the final WHERE clause put in the number for the second sampling cycle of interest (e.g., "Cycle = 2"). Save this as "t4".

Now join the tables from the two cycles and compute the difference between the two dates. We write the later time minus the earlier time so that changes are positive for increases and save the result in column "plantdiff". Call this query "t5":

```
SELECT t3.Node, t3.Plot, [t4].[ValueNz]-[t3].[Valuenz] AS plantdiff
FROM t3 INNER JOIN t4 ON (t3.Plot = t4.Plot) AND (t3.Node = t4.Node);
```

One more step, we want to the number of years between samples, so that we can normalize the change through time (there are likely to be minor differences in the length of time between samples at different nodes). This is a rather complicated task that is accomplished by this query (for sample cycles 1 and 2). The result is saved in column "yeardiff", which we save as query "t6":

```
SELECT yr1.Node, yr1.SampleYear, yr2.SampleYear, [yr2].[sampleyear]-
[yr1].[sampleyear] AS yeardiff
FROM (SELECT dbo_Node.Node, dbo_Node.SampleYear FROM dbo_SamplingCycle
INNER JOIN dbo_Node ON dbo_SamplingCycle.SampleYear =
dbo_Node.SampleYear WHERE dbo_SamplingCycle.Cycle=1) AS yr1 INNER JOIN
(SELECT dbo_Node.Node, dbo_Node.SampleYear FROM dbo_SamplingCycle INNER
JOIN dbo_Node ON dbo_SamplingCycle.SampleYear = dbo_Node.SampleYear
WHERE dbo_SamplingCycle.Cycle=2) AS yr2 ON yr1.Node = yr2.Node;
```

This result will be joined to the change data in the next step

B3. Join data to post-strata and cluster identifiers.

Summary statistics will usually be computed for post-strata, that is, classes assigned to the plots based on data from the sampling. We also need cluster (transect) identifiers so that the software can correct for the intercorrelation between plots in a transect. The R statistical software used for this purpose requires that clusters be identified by unique numbers, which are available in the "Transect" table. The following query takes the plant change values from t5 above, joins in the post-strata (Ecotype) and cluster identifiers (transect numbers) from the database, and the number of years between the sample events from t6 above, to get a table that we can use as R input. In this example it also selects out just the "Alpine" ecotypes; adjust this as needed.

```
SELECT dbo_Plot.Ecotype, dbo_Transect.TransectIndex, t5.plantdiff,
t6.yeardiff
FROM t6 INNER JOIN ((t5 INNER JOIN dbo_Plot ON (t5.Plot =
dbo_Plot.Plot) AND (t5.Node = dbo_Plot.Node)) INNER JOIN dbo_Transect
ON (dbo_Plot.TransectName = dbo_Transect.TransectName) AND
(dbo_Plot.Node = dbo_Transect.Node)) ON t6.Node = t5.Node
WHERE (((dbo_Plot.Ecotype) Like "alpine*"));
```

This table is ready for export to statistical software for further analysis. If you are analyzing just one year of data, replace all the "t5" entries above with "t3" and remove the references to "t6":

```
SELECT dbo_Plot.Ecotype, dbo_Transect.TransectIndex, t3.ValueNz
FROM (t3 INNER JOIN dbo_Plot ON (t3.Node = dbo_Plot.Node) AND (t3.Plot
= dbo_Plot.Plot)) INNER JOIN dbo_Transect ON (dbo_Plot.Node =
dbo_Transect.Node) AND (dbo_Plot.TransectName =
dbo_Transect.TransectName)
WHERE (((dbo_Plot.Ecotype) Like "alpine*"));
```

The output of these last two queries is be copied directly into a text editor window and saved as "rinput.txt" for analysis in R in the next step.

<u>B4. Compute mean change and test for significance.</u>

We use R statistical software and the "survey" package to compute statistics for our sampling design (R Core Team 2014, Lumley 2004). Open R and load the "survey" package. The following R code sets the "inpathfile" variable to a tab-delimited text file of data called "rinput.txt" (from output of the final query in the previous step.) Adjust the path and file name as needed. The data are read into a table called "dataset", and the columns are presumed to be named "TransectIndex" (the transect identifier numbers, the clusters), "Ecotype" (the ecotype names), "plantdiff" (the plant cover change values that we are testing), and "yeardiff" (the time in years between samples).

```
inpathfile <- "O:/Monitoring/Vital Signs/Terrestrial Vegetation and
Soils/Data/rinput.txt"
dataset <- read.table(inpathfile, header=TRUE, sep="\t",
na.strings="NA", dec=".", strip.white=TRUE)
```

If you want to work with differences normalized by the number of years, you can compute this and save in a new column called "value". The column "plantdiff" contains the amount of change and "yeardiff" contains the number of years (from the previous step):

```
dataset$value <- dataset$diff/dataset$yeardiff
```

We also have to load the stratum weights, which in our case are the percent cover of each Ecotype. These can be imported from a text file called "stratawts.txt" with columns named "Ecotype" and "weight" that is derived from Table 1. It is read into an R table called "strata" with these commands:

```
inpathfile2 <- "O:/Monitoring/Vital Signs/Terrestrial Vegetation and
Soils/Data/stratawts.txt"
strata <- read.table(inpathfile2, header=TRUE, sep="\t",
na.strings="NA", dec=".", strip.white=TRUE)
```

Next we define the sampling design with the "svydesign" command. It identifies the "TransectIndex" column as the cluster identifiers. The design is saved as "des1":

```
des1 <- svydesign(id = ~TransectIndex, data = dataset)
```

To compute the mean and confidence interval for the "value" column of a single Ecotype stratum run:

```
svymean(~value, subset(des1, Ecotype=="Alpine Dryas Dwarf Shrub"))
```

The "subset" command chooses one ecotype, in this case "Alpine Dryas Dwarf Shrub"; modify as desired.

To compute the means for each ecotype separately, run the "svyby" command:

```
svyby(~value, ~Ecotype, des1, svymean)
```

To merge multiple ecotypes, we need to incorporate the post-stratification weights stored in the table "strata", using the "postStratify" command. The result is stored as the variable "des1p":

```
des1p<-postStratify(des1, ~Ecotype, strata)
```

Now you can compute the weighted mean of "cover" for all of the ecotypes together:

```
svymean(~value, des1p)
```

To test if the mean cover is significantly different from zero using a t-test, use "svyttest". The first example computes an overall value for all the ecotypes, weighted by their area (as specified in the design "des1p" above). The second example tests just one ecotype as a subset of the data.

```
svyttest(cover~0, des1p)
svyttest(cover~0, subset(des1, Ecotype=="Alpine Dryas Dwarf Shrub"))
```

The t-test will give you a probability value that the difference was zero given your sample. Keep in mind that if the data are not normally distributed, the P-value could be inaccurate.

<u>B5. Interpret the results.</u>

In the case of tree diameters, cover by lichens and evergreen perennial plants, and height class of all woody plants, we assume that inter-annual (i.e. reversible) variations are minimal, and that the remaining errors (measurement error, minor mis-location of sample lines) are random. Thus any statistically significant change represents a "real" long-term change.

In the case of cover and height of herbaceous plants and cover (but *not* height) of deciduous shrubs, a statistically significant change could be due to a difference in growth stages between sample times or short-term, inter-annual fluctuations in total biomass production (due to summer warmth, for example). Our sample sizes will probably not be large enough to model the effect of the individual sample years, so we must subjectively interpret of the results. Here are some guidelines:

- Use very common plants or aggregations of similar plants (e.g. all *Carex* sedges together) so that the data includes samples from all years and many nodes. This will "average out" local or single-year effects.

- Examine ratios between groups of deciduous plants. For example, the ratio of willow to sedge cover should be less affected by timing of the sample than the absolute amount of either.

- Examine basal area of herbaceous species. Basal area changes less from year-to-year than leaf area. This is likely to be useful only for *Eriophorum vaginatum.*

- Check the timing of the samples. If a plot subset of interest happened to be sampled at markedly different dates in two successive sample years, consider this as a cause.

- Check the relative greenness of the sample years. We are monitoring greenness by satellite and remote automated cameras as a part of the ARCN vital sign "Terrestrial Landscape Patterns and Dynamics". If changes in deciduous plant cover in the plots of interest coincide with short-term changes in greenness, consider this as a cause.

- Finally, restrict conclusions to major changes. A change by some plant species from a minor (< 2% cover) to major (>20% cover) component is probably a long-term change, unless there is something highly unusual about the greenness or timing of one or both sample years.

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Appendix C: Standard Operating Procedures for ARCN-wide Lichen Community Composition Sampling

Standard Operating Procedure (SOP) # 1: Lichen macroplot setup and photography

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. Plot location

A1. Location of new plots from pre-selected coordinates

A1.1. Navigate to the coordinate location using a recreational-grade or high-resolution GPS. To avoid bias in the exact location of the plot, place the plot center at the point where the GPS coordinates first match the target coordinates, without adjusting for subsequent wandering of the coordinates. Temporarily place a survey pin at plot center.

A1.2. Set up a Trimble GPS unit to record an exact plot center location. Follow the latest guidance on Trimble best practices for obtaining the optimal accuracy. In 2011, the best practices were allowing the Trimble to record background data off plot for 30 seconds, collecting the center point data for 5 seconds, and proceeding off plot for an additional 30 seconds with the unit on. These measurements will be differentially corrected later.

A1.3. Dig a shallow slot approximately 10 cm deep and place a magnetic plot marker in it. Note that the black end of the magnet is marked “this end down”.

A2. Location of existing pre 2010 plots.

A2.1. Plot coordinates are in the project database, stored at https://irma.nps.gov/App/Reference/Profile/2166259/

A2.2. Navigate to the coordinate location using a high-resolution or recreational-grade GPS. Place a survey pin at the approximate plot center. Next use a high-resolution GPS (e.g., Trimble GeoXT, XM or XH) with real-time correction (SBAS) to attempt to find the location closest to the original plot center. Set the GPS down to allow it to begin averaging locations. For plot locations recorded with a Trimble previously, the actual GPS coordinate could be <1 m to 2 m from that coordinate. For locations recorded with a recreational-grade GPS (e.g., Garmin), the location could be 5-15m from the GIS coordinate. The lichen sampler may now begin working, with the understanding that the plot location could shift somewhat.

A2.3. Check photography to possibly refine the plot location as follows. In BELA and NOAT, the first photo is usually from plot center, with flags at the periphery and gear at plot center. Use landmarks to refine the plot center location if possible. If good landmarks are available (e.g., a distinctive rock at near plot center), you may use them to locate the plot center and use the GPS reading (part A2.3 below) to verify. In CAKR and KOVA the photography is representative of the site but not necessarily taken from the plot center. Check the photography to verify that the site generally matches the previous visit. For plots recorded previously with a Garmin GPS, extra efforts to locate a more precise plot center are recommended.

A2.4. After allowing the GPS to average for at least 10 minutes, note the average GPS reading and adjust the plot center location accordingly. This will become the permanently marked plot location. Dig a shallow slot approximately 10 cm deep and place the magnetic plot marker in it. (Note that the black end of the magnet is marked "this end down".) Set up the Trimble GPS to acquire a more exact location using the current best Trimble practices.

<u>A3</u>. Location of existing post-2010 plots (GAAR)

A3.1. Navigate to the general vicinity of the plot using recreational-grade GPS. Use a magnetic detector to locate the buried magnet and place a survey pin or flag over it.

B. Plot setup

The lichen sampler begins identification and collection work while the other worker continues with plot setup, photography, and site description. Wrap a survey stake at plot center once with a 100m tape at the 34.7 m mark. Stretch both ends of the tape out to mark the plot perimeter at magnetic cardinal directions from the center, placing one flag at 0m and the other at 69.4m. On rocky ground, it may be advantageous to have the lichen surveyor hold the tape at plot center. Repeat this exercise at approximately 90 degrees from the first tape line to place two additional flags. On steep plots the flags may be placed uphill, downhill and on-contour. Leave the tape set up in the plot during the reading to give an extra sign of the boundaries. Using two tapes at once is helpful for providing a good reference frame for the plot.

In the case of FIA epiphytic lichen "off-frame" plots compatible with the USDA-Forest Service-Forest Inventory and Analysis Program Lichen Indicator plots, please see Appendix C SOP #5 for other plot setup and surveying methods.

C. Photography

<u>C1</u>. From the plot center, shoot photos toward magnetic N, NE, E, SE, S, SW, W, NW. Use a 1/60 sec shutter speed unless vegetation is waving rapidly in the wind, in which case a 1/125 or 1/250 sec speed is desired. Shoot with lens zoomed to wide angle (18 mm on the Canon Digital Rebel SLR camera). Try to position the photo frame so that a small strip of sky is visible at the top of each

photograph, but raise the camera no higher than the point where the plot margin is at the photo center.

C2. Plot center photo from above, if there are features near the plot center that will be useful in locating the center in future years (e.g., rocks).

C3. Backup photos to a field laptop each evening and leave the photos on the camera's memory card also. Each plot requires 8 or 9 routine photographs. Thus for 5 MB photographs a typical plot will require about 50 MB of space, and a field trip of multiple weeks duration with should fit on a standard 4 GB memory card.

Standard Operating Procedure (SOP) #2: Lichen macroplot site attributes

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. Site Attributes

Site attributes are recorded on a data recorder with number keypad. The list below includes the abbreviations for the data elements used.

Plot. The plot identifier.
Date. Use Mon/Day/Year format.
Time. Note AM or PM. Used to solve problems with photo or GPS labels.
Microfeature 1. Patterned ground feature: NC - nonsorted circles; SC - sorted circles; HP - high-center ice wedge polygons; LP - low-center ice-wedge polygons; EH - earth hummocks; TU - tussocks;
Microfeature 2. Second patterned ground feature if two are present
Position. Position on the slope (Fig. B5): SU - summit, SH - shoulder, BS - backslope, FS - footslope, TS - toeslope
ShapeVert. Slope shape in an up-downslope direction: CC - concave, LI - linear, CX - convex.
ShapeHoriz. Slope shape parallel to the elevation contours.
Aspect. The direction toward which the surface of the soil faces, expressed as an angle between 0 and 360 degrees measured clockwise from true north.
Gradient. Surface slope gradient of the plot.
FloodFreq. Flooding frequency: NONE - never; RARE - 1-5yr/100y; OCC - 5-50yr/100yr; FREQ - >50yr/100yr
Efferv. Effervescence class of a representative rock: NONE - no reaction; SLIGHT - bubbles; STRONG - foam. Use 1M HCl; to identify calcareous substrates. For rocks soft enough to scratch with a knife that effervesce weakly or not at all, test a powder scratched from the rock with a knife.

The next 12 fields are percent cover by various plant groups or soil cover types. The classes are 0.5, 1, 3, 5, 10, 15, 20, …, 95, 100%. Round to the nearest class and use “0.5” to mean “less than 0.5”. A circle 2.2 m in diameter (i.e., just beyond your armspan) covers 0.1% of our 0.378 ha plot. Use Fig. C1 to aid in estimates.

Tree. Spruce, tree birch, aspen, or cottonwood, any size class
Tall Shrub. Shrub birch, alder, or willow, > 1.5 m tall
Low Shrub. Shrubs 0.2 to 1.5 m tall
Dwarf Shrub. Shrubs < 0.2 m tall
Gram. Graminoids.
Forb. Forbs
Bryo. Bryophytes
Lichen. Lichens (including both macrolichens and crustose lichens on all substrates)
Soil. Bare mineral soil plus gravel, particles up to 75 mm diameter
Duff. Bare organic soil (duff)
Rock. Exposed bedrock, boulders, and cobbles (down to 75 mm diameter)
Water. Standing water

For back compatibility with pre-2010 data, the first revisit to plots established before 2010 should also include:

MidTallShr. Shrubs above knee height
LowShr. Shrubs below knee height
Other. Forbs, Dryas, and other non-woody dwarf shrubs.

Continuing with site attributes:

VegClass 1. Viereck et al. (1992) level IV vegetation class for the whole plot if only one class present, or one of two if two are present
VegClass 2. Viereck et al. level IV vegetation class for the second class if two are present
VegClass 1%. Proportion of the plot occupied by Veg1.
VegClass 2%. Proportion of the plot occupied by Veg2.
LichenUtil. Lichen utilization class (Table B1).
InitialsSite. Initials of the person who did the site description.
InitialsLichens. Initials of the person who did the lichen sampling.

B. Lichen Mat Height

The mat height of the plot's macrolichens will be assessed as follows. A 3 mm diameter metal rod with a thin plastic ruler glued on is the measuring probe. Twenty-five measurements are obtained on each plot as follows : 6 points are surveyed in each of the cardinal directions along the tapes starting at a distance of 9 meters from the center and sampling each successive 5 m. One final point is obtained at plot center. Thus the distances at which lichen heights are measured are 9, 14, 19, 24, 29, and 34 m of each cardinal direction and plot center. At each point, the measuring probe is inserted into the tundra mat until significant resistance of a hard layer is felt. The mat height is then measured by measuring the highest height of the lichen touching the probe. If no lichen is touching the probe, then the height of the nearest lichen is measured at its highest point. The species of each lichen measured is recorded.

The first round of monitoring for the WEAR parks included 5 height measurements per target taxon per plot of the following species: *Cladina arbuscula/mitis*, *Cladina rangiferina*, *Cladina stygia*, *Cetraria cucullata*, and *Cetraria islandica*. In plots where one or more of these species were absent, the following substitutions were permissible: *Alectoria ochroleuca*, *Alectoria nigricans*, *Bryocaulon divergens*, *Thamnolia subuliformis/vermicularis*, *Cetraria laevigata*. To allow trends to be computed using old data, at the first remeasurement of these plots make sure there are at least 5 measurements of each of the target species or substitutes per plots (with 5 taxa per plot). The extra measurements not at the regular distances above are to be placed in the "extra height measurements " field, not with the systematic mat height measurement group.

C. Vascular and bryophyte composition

Vascular and bryophyte plant composition is recorded for site characterization purposes. The list is typically compiled by the assistant after GPS, photography, and site characterization are finished, in the time available while the lichen sampler is finishing; it is not considered exhaustive. Identify all species with 1% or greater cover and collect if needed. Generic names (e.g., *Carex*, *Sphagnum*) may be used if needed. All plants, including trees, shrubs, herbs, and mosses, should be captured here.

Plants are recorded using dropdown lists on the data recorder that are based on the NPSpecies lists for the NPS unit plus higher taxa and unknowns. Collections of unknowns are labeled sequentially at each plot and labeled as such on the plant press sheets or collection packets.

The abundance scale for vascular plants is the classic relévé cover scale:

+	<1%
1	1-5%
2	6-25%
3	26-50%
4	51-75%
5	76-100%

Use Fig. C1 to aid in estimates.

D. Field Data Backups

Each evening a copy of the site data spreadsheet containing data cumulative to that date should be saved as a backup: 1) in a subfolder labeled "backups" in the data recorders main memory, and 2) a USB device (thumb drive) or the field laptop computer. These files should be given daily names to avoid overwriting. The daily backup files should thus be named "LichenSiteYYxMMMDD.xls", which is the filename "LichenSiteYYx" plus the 3-letter month "MMM" and two-digit day "DD". The original file "LicheSiteYYx.xls" remains in the data recorder's My Documents\Business folder and is added to each day until the end of the field trip.

E. Return visits

<u>E1</u>. First return visits to pre-2010 plots. All data elements should be recorded. Subsequently these plots can be treated like post-2010 plots below.

E2. Return visits to post-2010 plots. All site data elements that involve vegetation and ground cover must be recorded, along with the Plot identifier, sampler initials, Date, and Time (the "plot" field plus all data elements starting with "tree" to the end of the list in section A above). All remaining elements are stable landform characteristics that should be checked and corrected if needed.

F. FIA Plots

If a plot is more than 15% forested, it may also be simultaneously sampled as an off-frame FIA lichen indicator plot, which includes only epiphytic macrolichens. This requires a separate form with additional data fields (see SOP #5). The subset of species and vouchers pertaining only to the epiphytic FIA samples must be distinguished from the ARCN plot as a whole.

If the full 2 hours is required only for the epiphytic macrolichen collections of the FIA plot, then a third hour may be added to accommodate the terrestrial species also required for the ARCN plot.

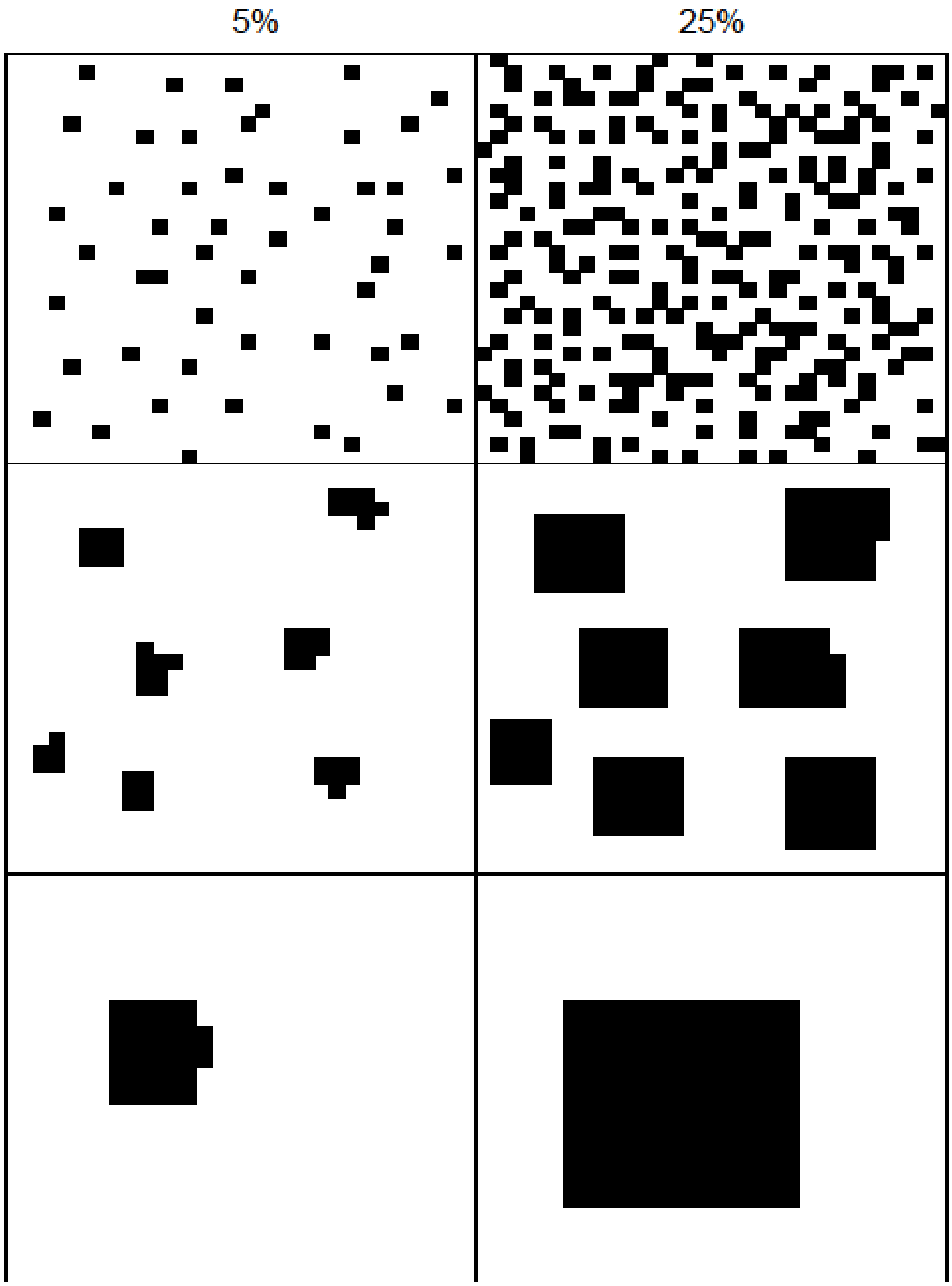

Figure C1. Cover estimate guide.

Standard Operating Procedure (SOP) #3: Lichen macroplot species sampling

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. General

This SOP is a minor modification of the National FIA lichen sampling protocol (USFS 2011). The main modification is to the abundance scale, which was originally designed for epiphytic lichens. The plot size is the same, though the diameter has been reduced slightly from the FIA plot because the latter has some unsampled areas. The lichen sampler searches for macrolichen species with the time constraints as in the FIA protocol: a minimum of 45 minutes and a maximum of two hours, or until 10 minutes elapse with no additional species recorded after the 45 minute minimum. If an FIA plot for epiphytic macrolichens is being conducted simultaneously (See SOP#5), then a maximum of 3 hours may be used to complete the species search for both the FIA and ARCN plots.

B. Abundance estimates

Lichen abundance is estimated according to the following scale:

1 = rare (<3 thalli)
2 = uncommon (4-10 thalli)
3 = common (>10 thalli and <1% cover)
4 = abundant (1-5% cover)
5 = prolific (6-25% cover)
6 = dominant (>26% cover)

Use Fig. C1 as a guide for cover estimates. Abundance estimates are recorded on the collection packets for collected species. Species that are not collected are recorded in a waterproof pocket notebook or on a lichen checklist form on waterproof paper (Fig. C2). In the field notebook or form, the sample is identified by the date and plot identifier, and the full Latin name is given for each species along with its abundance class. Abundance estimates should be made without collections only for taxa with no known look-alikes (e.g., *Flavocetraria cucullata*, *Alectoria ochroleuca*). Please note: if an FIA plot is conducted for epiphytic macrolichens simultaneously, see SOP#5 for separate abundance coding.

C. Collections

Collections are made of all species for which there is any question about identification. Collections are made in paper envelopes and labeled with the date, plot identifier, sequential sample number, abundance class, and tentative name or notes. The purpose of the latter is mainly to avoid duplicate or missed collections. Collections may be made within the plot to save time. Wet collections should be dried as soon as possible.

Observers: ____________________ Date: ______________ Plot: ________________

____ Alectoria nigricans
____ Alectoria ochroleuca
____ Allantoparmelia almquistii
____ Allantoparmelia alpicola
____ Arctoparmelia centrifuga
____ Arctoparmelia incurva
____ Arctoparmelia separata
____ Asahinea chrysantha
____ Asahinea scholanderi
____ Bryocaulon divergens
____ Bryoria chalybeiformis
____ Bryoria lanestris
____ Bryoria nadvornikiana
____ Bryoria nitidula
____ Cetraria andrejevii
____ Cetraria chlorophylla
____ Cetraria commixta
____ Cetraria cucullata
____ Cetraria delisei
____ Cetraria halei
____ Cetraria hepatizon
____ Cetraria islandica
____ Cetraria kamczatica
____ Cetraria laevigata
____ Cetraria nigricans
____ Cetraria nivalis
____ Cetraria pinastri
____ Cetraria sepincola
____ Cetraria subalpina
____ Cetraria tilesii
____ Cladina arbuscula
____ Cladina mitis
____ Cladina rangiferina
____ Cladina stellaris
____ Cladina stygia
____ Cladonia amaurocraea
____ Cladonia bacillaris
____ Cladonia bacilliformis
____ Cladonia bellidiflora
____ Cladonia botrytes
____ Cladonia cariosa
____ Cladonia carneola
____ Cladonia cenotea
____ Cladonia chlorophaea
____ Cladonia coccifera
____ Cladonia coniocraea
____ Cladonia cornuta
____ Cladonia crispata
____ Cladonia deformis
____ Cladonia digitata
____ Cladonia ecmocyna
____ Cladonia fimbriata
____ Cladonia gracilis
____ Cladonia maxima
____ Cladonia metacorallifera
____ Cladonia norvegica
____ Cladonia ochrochlora
____ Cladonia pleurota
____ Cladonia pyxidata
____ Cladonia scabriuscula
____ Cladonia subfurcata
____ Cladonia sulphurina
____ Cladonia uncialis
____ Cladonia verruculosa
____ Cladonia verticillata
____ Cladonia wainioi
____ Cladonia sp. __________
____ Cladonia sp. __________
____ Cladonia sp. __________
____ Cladonia sp. __________
____ Cladonia sp. __________
____ Cladonia sp. __________
____ Coelocaulon aculeatum
____ Collema __________
____ Dactylina arctica
____ Dactylina beringica
____ Dactylina ramulosa
____ Dermatocarpon ________
____ Evernia mesomorpha
____ Hypogymnia austerodes
____ Hypogymnia bitteri
____ Hypogymnia physodes
____ Hypogymnia subobscura
____ Leptogium lichenoides
____ Leptogium saturninum
____ Lobaria linita
____ Lobaria scrobiculata
____ Masonhalea richardsonii
____ Massalongia carnosa
____ Melanelia exasperatula
____ Melanelia olivacea
____ Melanelia septentrionalis
____ Melanelia stygia
____ Mycoblastus sanguinarius
____ Nephroma arcticum
____ Nephroma bellum
____ Nephroma expallidum
____ Nephroma helveticum
____ Nephroma parile
____ Nephroma resupinatum
____ Pannaria pezizoides
____ Parmelia omphalodes
____ Parmelia saxatilis
____ Parmelia sulcata
____ Parmeliopsis aleurites
____ Parmeliopsis ambigua
____ Parmeliopsis hyperopta
____ Peltigera aphthosa
____ Peltigera canina
____ Peltigera didactyla
____ Peltigera leucophlebia
____ Peltigera malacea
____ Peltigera polydactyla
____ Peltigera rufescens
____ Peltigera scabrosa
____ Peltigera venosa
____ Physconia muscigena
____ Physcia aipolia
____ Physcia caesia
____ Physcia dubia
____ Pseudephebe miniscula
____ Pseudephebe pubescens
____ Psoroma hypnorum
____ Ramalina dilacerata
____ Ramalina roesleri
____ Solorina crocea
____ Solorina saccata
____ Sphaerophorus fragilis
____ Sphaerophorus globosus
____ Stereocaulon alpinum
____ Stereocaulon glareosum
____ Stereocaulon grande
____ Stereocaulon intermedium
____ Stereocaulon paschale
____ Stereocaulon rivulorum
____ Stereocaulon saxatile
____ Stereocaulon tomentosum
____ Thamnolia subuliformis
____ Thamnolia vermicularis
____ Umbilicaria arctica
____ Umbilicaria caroliniana
____ Umbilicaria cinereorufescens
____ Umbilicaria cylindrica
____ Umbilicaria deusta
____ Umbilicaria hyperborea
____ Umbilicaria probiscidea
____ Umbilicaria torrefacta
____ Umbilicaria vellea
____ Xanthoria borealis
____ Xanthoria elegans
____ Xanthoria polycarpa
____ Xanthoria sorediata
____ ______________
____ ______________
____ ______________
____ ______________
____ ______________
____ ______________
____ ______________
____ ______________
____ ______________

(1) 1-3 thalli (2) 3-10 thallii (3) <1% (4) 1-5% (5) 5-25% (6) >25%

Figure C2. Lichen field checklist form.

Standard Operating Procedure (SOP) #4: ARCN-wide Lichen Community Plot Post-field Procedures

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. Photography

A1. Download photographs into a folder labeled by the NPS unit and year, placed in the photographs folder under the project file on the O (ARCN) drive.

A2. Create a catalog of the photos. The catalog will includes columns for the date, time, file size, file name, plot, view, and note. We will also create the NPS mandatory metadata fields (see A2.4). The catalog may be created using specialized photograph catalog software, or using any spreadsheet software as described below.

A2.1. To create a photograph catalog spreadsheet, write the contents of the folder containing the photographs to a file and open in spreadsheet software. In the Microsoft Windows environment, this can be accomplished by creating a text file with the following command:

```
dir /n >photolog.txt
```

The file name after the ">" is your option. Save this line of text in a file with *.bat extension, e.g., "filelist.bat" in the folder where the photos are. Next, double-click on the bat file and a directory of the folder will be written to the text file ("photolog.txt"). Open the text file in your text editor, delete all of the lines that do not contain a photograph file names, and save. Import this text file into your spreadsheet as a "Fixed width" text file. Label the columns (date, time, size, filename), add new columns called "plot", "view", "note", and save as tab-delimited text.

A2.2. For plot photography, photographs taken in the proper order may be labeled in batches by copying the plot name to the entire range of consecutive photos from the plot, and by copying the following column of cell values into the "view" column:

```
toN
toNE
toE
toSE
```

```
toS
toSW
toW
toNW
center
```

A2.3. For photos not taken on a plot, the “Plot” column may be left blank and the location described under “View”.

A2.4. Populate the NPS mandatory photo metadata fields. Add the following columns to your spreadsheet and populate them as indicated.

Title – concatenate Plot, View, and Note
Image_Content_Place – populate this with the WGS84 latitude and longitude, separated by a comma. For photos taken on plots, you can make a database join with your plot GPS data, though it may be faster simply to copy and paste the values. For photos taken off plots, use GPS linking software to add the coordinates.
NPS_Unit_Alpha_Code – ditto the 4-character park code
Metadata_Access_Constraints – fill this in with the word “public”
Contact_Information – “NPS Fairbanks Alaska administrative center”

B. Site data

B1. Enter site data into a spreadsheet patterned after the field form. For the fields with specific text entries, either use a drop-down menu, or type the codes and verify them using a crosstab (pivot) table to locate errors.

B2. After data entry is complete, highlight the data, copy, then paste special (transpose) to a new workbook.

B3. Import the transposed data into Access as the table ImportLichenSiteYY. All the number fields should be imported as integers, all others as text.

B4. Append the data to the “LichenPlot” master table in the database.

C. Lichen data

C1. After identification of lichen collections is complete, the data are entered from both the field notebook (species not collected) and the field collection (unknowns) packets. Data may be entered into a spreadsheet in list (database) format using dropdown choice lists to ensure accuracy, or typed using species codes and the PC-ORD compact format, as described in part C3 below.

C2. If entering data into a spreadsheet using the list format, the spreadsheet columns are

Year – 4-digit calendar year; ditto through the entire year’s data set
Plot – the plot identifier; ditto through each species on that plot
Taxon – the full taxon name taken from the choice list. This will usually be a species name, taken from a dropdown list consisting of NPSpecies species listed for the NPS unit. Higher taxa and species groups may be added to this list.

Abundance – the abundance class, 1 through 6

After entry and error-checking, these data are added directly to the Lichen Species database table with an append query.

C3. An alternative is to type data in the “compact” format of PC-ORD software (http://home.centurytel.net/~mjm/pcordwin.htm) using codes for species. (Long dropdown lists, as in step C2 above, are clumsy.) Data are typed into a text editor or a word processor and saved as text. A convenient set of 6-letter or 6 number codes for lichens has been developed for this purpose in previous work and is maintained by ARCN. The “compact” file format specifications are given in the online documentation for PC-ORD, and PC-ORD is used to convert to list format. The columns in the output file are the same as those described above for the list format, minus the year, which must be added. After the compact data have been converted to list format, import into a database and run a database join with your master list of codes and species names to add the full species names. The codes must be unique. Check for erroneous codes (missing from the master list). Error check the full species names and abundances against the field data.

Standard Operating Procedure (SOP) #5: Special Data Fields for FIA Lichen Indicator Off Frame Plots

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. When to Complete FIA Off-Frame Data Fields.

Although most of the Arctic Network landscape is treeless, there are areas of boreal forest and spruce-lichen woodland. In these areas, ARCN lichen monitoring plots are made useable by the USDA-Forest Service/Forest Inventory and Analysis Program Lichen Indicator (FIA Lichen Indicator; USFS 2011) with the incorporation of a few additional pieces of data. The FIA Lichen Indicator frequently uses “off-frame” plots (i.e., plots not on their normal sampling grid) for constructing lichen air quality models and for extending coverage to areas not on the normal sampling grid. Since our plot layout, lichen collection methods and secondary variables mostly overlap the FIA methods, there are only a few additional steps that need to be taken to turn these plots into off-frame FIA lichen plots. These steps should be taken whenever the cover of trees on the plot is at least 15% (the cutoff for FIA monitoring).

B. Denoting Presence of Lichen Taxa as Epiphyte and the Abundance

The FIA lichen community protocol includes only epiphytic lichens from at least 0.5m above the ground. When filling out the data sheet or using the field notebook to record species that are identifiable in the field, a special notation using an “E” prefix with the abundance code should be made next to that taxon to denote that it is present as an epiphyte. For example E-3 denotes an epiphyte with an abundance code of 3. The same notation is used in the abundance field on collection packets.

The FIA lichen abundance codes are as follows:

1. 1-3 thalli
2. 4-10 thalli
3. >10 thalli but less than code 4
4. >50% of all available substrates host this species

C. Other Environmental Data Fields

Additional environmental data variable will need to be collected. These should be entered onto a waterproof paper form for FIA Lichen Indicator Off-frame data, with the following fields:

Plot. The plot identifier
Sz3Trees. Size class of three largest trees (Choices: <10 in, 11-20 in, 21-20 in, 21-30 in 31-40 in,>41 in)
GapTree. Proportion of plot occupied by a tree canopy gap (i.e., a contiguous area absent of trees)(Choices: 0, 1, 3, 5, 10, 15, 20….85%)
GapNoShrub. Proportion of plot occupied by treeless and tall shrubless canopy gap (Choices: 0, 1, 3, 5, 10, 15, 20….85%)
GapWithShrub. Proportion of tree canopy gap with medium to tall hardwood shrubs or chronically subdominant hardwood trees (Choices: 0, 1, 3, 5, 10, 15, 20….85%)
OldTrees. Proportion of plot occupied by "old-growth" trees, based on local definition for white spruce.
AgeClass. Stand age class (Choices: 1: Shrub/forb 0-30, 2: Seedling/sapling 30-100, 3: Mid 100-200, 4: Mature 200+, 5: Old-growth 300+)
DiversityFeat. Features important for high/low lichen diversity, if any. (Comment field)

The FIA off-frame plots also require cover class assignments for dominant tree and shrub species, which were covered previously in SOP #2.

D. Tree counts with Basal Area Prism.

In each plot, 5 measurements of conifers and of hardwoods need to be made with a basal area prism. The measurements should be made at the plot center and in each of the 4 cardinal directions, halfway out to the perimeter of the plot. Normally either a 10 or 20 factor English unit prism will be used. Select the prism with the lowest factor that results in no more than 10 to 15 trees tallied per point.

Hold the prism over a center point, at a right angle to the line of sight. If the eye is over the point, bias is introduced. The prism should be oriented such that the wedge shape points left or right, not up or down.

Sight prism with top edge at breast height on target tree.

Using one eye, if the image of the tree in the prism overlaps with the rest of the tree, count the tree as "in". If the image of the tree in the prism is completely non-overlapping with the tree, the tree is out. Count half of the borderline trees as "in".

These data are recorded in the following fields on the FIA Off-Frame Plot data form.

BAF. Basal area factor of the prism.
cntrCon. Count of "in" conifers from the plot center.
cntrHdwd. Count of "in" hardwoods form the plot center.
1Con. Count of "in" conifers from the first position halfway to the plot periphery in the 1st cardinal direction.

1Hdwd. Count of “in” hardwoods from the first position halfway to the plot periphery in the 1st cardinal direction
2Con. As above for conifers from 2nd cardinal direction position.
2Hdwd. As above for hardwoods from 2nd cardinal direction position.
3Con. 3rd position conifers.
3Hdwd. 3rd position hardwoods.
4Con. 4th position conifers.
4Hdwd. 4th position hardwoods.

Appendix C Literature Cited

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Appendix D: Standard Operating Procedures for Mine Haul Road and Exclosure Monitoring Plots

These SOPs were developed for the Red Dog Mine haul road monitoring plots. The exclosure monitoring uses the same plot design, with the only difference being the plot location procedures, which are described in sections 4 and 5 above.

Standard Operating Procedure (SOP) # 1: 4 X 8 m plot setup, photography, and measurement

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. Locating and marking plots

A1. Locating new plots. Use a Trimble GPS to navigate to the pre-determined plot coordinates. Use the Find Waypoints function on the GPS to display an azimuth and distance to the desired point. Move slowly when approaching the desired coordinates to allow the GPS to equilibrate. Stop when the distance to the waypoint first reaches a value of less than 1 m. For plots 100 m or less from the road, use a tape measure or other measuring device with accuracy of 2% or better to verify the distance from the road and adjust by moving perpendicular toward or away from the road as needed. Mark the waypoint and set up the Trimble GPS to get a more exact location. Location data should be obtained with a high resolution GPS such as the Trimble GeoXH capable of 10-50 cm accuracy after differential correction post-processing. Pound a roughly 16 inch rebar stake or spike into the ground and affix a plot number tag to the top with galvanized wire. Also, place the magnetic plot marker in a shallow slot approximately 10 cm deep. Note that the black end of the magnet is marked “this end down”. For new road study plots, the plot will be aligned parallel to the road; record the azimuth (relative to true north) of the long axis of the plot. The stake and magnet will be located at the corner nearest the road, at the north or west end of the plot, depending on its orientation.A2. Locating existing plots. The Red Dog Mine haul road monitoring plots are in the project database stored at https://irma.nps.gov/App/Reference/Profile/2166259/. Use a GPS to navigate to the coordinates of existing plots and a magnetic detector to locate the rebar spike. For plots with a rebar stake only, place the magnetic plot marker in a shallow slot approximately 10 cm deep. Note that the black end of the magnet is marked “this end down”. For the Red Dog road plots, the corners of the plot which bears the stake is variable, as is the azimuth, and both are in the database. In general, for plots on the north side of the road, the stake is in the southwest corner, while for plots on the south side of the road, the stake is in the northwest corner.

<u>A3. Marking plot boundaries</u>. Mark the plot boundaries using 50 m metric measuring tapes along the long sides and ropes on the short side (Fig. 10).). Ensure that the plot's angles are 90° as follows.

1) Placing a colorful survey pin (A) at the corner stake

2) Placing a second pin (B) 8 m from the first pin in the desired direction based on the compass bearing in the database (from true north)

3) Place the third marker (C) tentatively 4 m and 90 degrees from the second marker and in the proper direction.

4) Square this marker by measuring the hypotenuse from the first to the third stake as follows:

    a) Hold one tape at stake A and draw it out to 894.5 cm

    b) Hold another tape at stake B and draw it out 400 cm

    c) Set stake C where the 2 tapes intersect

5) Hold one tape at stake C and draw it out to 800 cm

6) Hold another tape at stake A and draw it out 400 cm

7) Place stake D where tapes intersect

B. Photography

After the plot boundaries have been marked with measuring tape and rope, shoot photographs of the plot from each of the two long sides beginning with the long side nearest the road. The range of the photos should be such that the plot fills most of the frame from a side-to-side. The vertical view angle should place the plot in the middle and lower half of the frame. Shoot additional close-ups of the plot if desired.

C. Site characteristics

Site attributes are recorded on a waterproof paper form or data recorder with number keypad. Fields are the same as on lichen macroplots (Appendix C, SOP #2, Part A) with the exceptions listed below.

<u>Plot</u>. The plot identifier. For pre-2013 Red Dog Road plots these have been determined. While it is not anticipated that any new Red Dog plots would be needed, we include the naming conventions here should the need arise. New plots in CAKR should be named as follows. The first letter (E or T) refers to the landcover types in Jorgenson (2009), either Upland Moist Dwarf Birch-Ericaceous Shrub (E) or Upland Moist Dwarf Birch-Tussock Shrub (T). The second character is the transect number. The third character is the location either north (N) or south (S) of the haul road. The final numbers refer to the distance from the road. For some plots, a final character "A" is added as an

"autocorrelation" plot approximately 10-20 m from a plot at the 1000, 2000, or 4000 m distances from the haul road.
Road dust observed. Yes or No. This field is used only on the Red Dog Haul Road plots

D. Species Data

There are two types of data that will be collected on plots: species present at point intercepts and other species present on the plot but not recorded at the points.

D1. Points are located along a 4 m PVC pipe with 10 pre-measured points at 40 cm intervals beginning 20 cm from the end. Make 10 pipe placements, starting at the west end and advancing the pipe 80 cm between placements (Fig. 10). The point counts are designed to sample the population as a whole, rather than to track the exact changes at any given point over time, so we expect that the points will not fall on exactly the same spot in different survey years.

D2. At each point, use a laser pointer on a rod approximately 90 cm long to mark the points (Fig. 10). At the first PVC pipe placement (on the plot boundary), the rod is placed against the mark on the PVC pipe such that the arm holding the laser extends beyond and into the plot. Hold the laser point in a similar fashion at subsequent PVC pipe placements. Note each plant species touched by the laser beam. Lichens and vascular plants should be recorded to species or collected. Bryophytes should be recorded to the functional groups established for the node plots (Appendix B) and the lichen community composition plots (Appendix C).

D3. Data are recorded in the Trimble Nomad or similar device. A new blank data file is started each day, and thus only one day's data is in each file. The file naming convention is RedDogPtsDTMONYR.xls or ExclPtsDTMONYR.xls for all files, where DT is the date, MON the month, and YR the year. The point data itself is recorded on the worksheets "Sheet1", "Sheet2", "Sheet3", etc. sequentially for each plot through the day. Record the plot identifier at the top of the form, and then move sequentially down the form, making sure that the point identifier matches the location being read. In the point names, X to refers to the position (in centimeters) on the tape down the long dimension of the plot, and Y refers to the position on the 4 m PVC pipe, numbered 1 through 10 from left to right as you face from 0 m end of the plot toward the 8 m end. Thus the point name "X120_Y3" refers to a placement of the PVC pipe at 120 cm on the tape (the fourth placement, after 0, 40, and 80 cm), and the third point (out of ten) from the left end of the PVC pipe.

D4. The data recorders are populated with the list of all lichens recorded to date in ARCN (the *L* list), all vascular plants in the park unit (the *V* list), selected Bryophyte taxa (the *B* list), genera of lichens plus codes for unknowns (the *HL* list), and vascular genera and families (excluding some small monogeneric families) plus codes for unknowns (the *HV* list). The user can also populate another list of commonly encountered plants, drawn from the prior lists and called the shortlist (list *S*, found on worksheet "Shortlist"), and a list of unknown plants (the *U* list, found on the "Unknowns" worksheet). When recording a plant name for a point intercept (on "Sheet1" etc), the recorder first chooses a list from the first column (the default is *S*), and then a plant name from the corresponding dropdown list in the second column. Recording is much easier with a good shortlist, which is populated ahead of time. Note that the shortlist remains available for each plot in the file.

D5. Unknowns in the point-intercept samples. When an unknown plant occurs on an intercept point, it is added to the list on the "Unknowns" worksheet and then becomes available for use on the point form by choosing the "U" list. Unknowns are automatically numbered sequentially, and the investigator normally gives them a higher taxon name or unknown code from the HL or HV list; the investigator may also add a note to help recall the unknown on subsequent points (e.g., "ball-head" to go with an unknown *Carex* if there are several). The concatenated number, taxonomic name, and note are listed on the "U" list for use on the point-intercept form. Unknowns are collected and labeled with the plot, date, unknown number, and the tentative name. (Collections may also be made of plants identified to the species level, in which case there is no unknown number.) Unknowns may be used repeatedly in a single data file (i.e., on several plots during a single day). However, lichen unknowns normally are re-entered, receive a new number, and are collected at each new plot because matching them between plots can be unreliable.

D6. Ground cover. Our data forms have space for 5 strata of plants and a line for the ground cover (labeled *G*; Table B4). All points should have a ground cover recorded. If the point is occupied by a living plant base (most often a shrub or tufted graminoid), record the ground cover as BasalVeg. If there is a lichen/algae crust directly on soil, record it as a ground cover of cryptogammic crust (and don't record crustose lichen in the plant line).

The height column on the G line is used to record the thickness of the moss-lichen mat. To accomplish this, a 3 mm rod with a ruler strip glued on is inserted into the tundra mat until it reaches the definite resistance of a compacted O layer of the soil, or rock or mineral soil. This should in most cases be the interface between the bottom of the live lichen mat and the top of the soil profile. If there are no nonvascular plants present, record a thickness of zero; this cell should always have an entry.

Many workers find it helpful to copy a default ground cover in every blank for a given plot. To accomplish this, scroll right to the worksheet labeled "DataTemplate". In the first blank for groundcover (row 8, column B), select the groundcover you want for the default. Next press the button "CreateForm". This will ditto your choice down the form. Now select column B, copy it and paste into the sheet where you want the default groundcover to appear. Note: adding a default ground cover can only be done before you start recording data on a plot, because in the paste operation you will overwrite any plant names with blanks.

D7. At each point, the height of the lichen mat is measured to the nearest mm. To accomplish this, a 3 mm rod with a ruler strip glued on is inserted into the tundra mat until it reaches the definite resistance of a compacted O layer of the soil, or rock or mineral soil. This should in most cases be the interface between the bottom of the live lichen mat and the top of the soil profile. As lichens are measured for mat height, the name of each species should be recorded with its height. At the completion of each plot, we need to assure that each of the following taxa has at least five measurements: *Cetraria cucullata*, *Cetraria islandica*, *Cladina stygia*, *Cladina arbuscula*/*mitis*, *Cladina rangiferina*. If one or more of these is not on the plot, the following substitutes may be made: *Cetraria laevigata*, *Thamnolia subuliformis*/*vermicularis*, *Alectoria nigricans*, *Alectoria ochroleuca*, *Bryocaulon divergens*. If it is not possible to get 5 of the target species, get as many as possible. To record species not present in the mat height point survey, species heights will need to be placed in an “extra species measurements” field.

D8. As in the lichen community composition protocols, only species definitely known in the field are recorded to the species level in the data. All others are recorded as unknowns and collected in a field packet. The packet should have fields allowing space for recording: plot number, point number, collector name, species (e.g., “*Cladonia* sp, like cornuta”, abundance. All taxa encountered on a point receive an abundance of 1%, or simply 1. It is helpful to have a field on the collection packet allowing the user to circle either “point count” or “trace”. If the same unknown is found at multiple points make sure the abundance and point numbers are updated on the packet.

D9. After completing the point counts, a thorough search of the plot is conducted to find all additional lichen species. These species will be assigned a trace abundance value in the database. Use the lichen macroplot form on waterproof paper (see Appendix C, SOP #3). Unknowns are collected in the field packets and added to the database as trace species after identification.

E. Moss tissue collection.

Near each plot and at approximately the same distance from the road, a one liter sample of *Hylocomium splendens* should be obtained. Samples should be compacted as much as possible, so that the sample is dense and would represent several liters loosely packed. Samples should be packed into a large Ampac Specipak bag or similar, using latex or nitrile gloves to obtain the collection. Specimens should be labeled with the date, species, plot number and collector, and should then be double bagged into a quart Ziploc. Specimens need to be kept frozen or on ice during the sampling time, and then handled according to the instructions of the Wet/Dry Deposition moss protocol.

Standard Operating Procedure (SOP) #2: 4 X 8 M plot post-field procedures

Version 1.0 (Mar 2014)

Revision History Log:

Version No.	Revision Date	Author	Changes Made	Reason for Change

A. Daily data backups.

Each day after returning to the lodging or basecamp, backups should be made on the project laptop of the GPS data files, the Nomad data files and the photos. Backups should be additionally copied into backup folders on the data recorder. The point intercept data file has a unique name based on the date and may be copied without renaming.

B. GPS data.

Trimble GPS data should be aggregated and postprocessed using the closest base station with high integrity GPS. These data should then be exported to a GIS-accessible file. See Appendix B, SOP #7 for details.

C. Site data.

Site data are entered as described for lichen macroplots in Appendix C, SOP #4, part B.

D. Point-intercept data.

See Appendix B, SOP #7, part C

E. Species identifications.

Lichen species should be identified using standard microchemical tests (e.g., KOH, Sodium hypochlorite, and paraphenylene-diamine) but excluding analysis of lichen secondary compounds by thin layer chromatography. The taxonomy used in the 2006 sampling of these plots agrees with the 16th North American Lichen Species Checklist (Esslinger 2010), with the following exceptions: *Cladina* Nyl. species were retained in that genus rather than regrouped into *Cladonia*. *Cetraria* species were retained in that genus rather than several derivative genera (e.g., *Flavocetraria*, *Vulpicida*). *Melanelia* was retained for the two species present rather than *Melanohalea*. Species concepts followed Goward (1999) for fruticose lichens and Goward et al. (1994) for foliose lichens. It is highly recommended that identifications of problem material be based on several lichen manuals, and others that could be of assistance include Brodo et al. (2001) and McCune and Geiser (2009). Vascular plant taxonomy and species concepts followed Hulten (1968). All identifications based on future manuals should be made back-compatible with these concepts via a "track species changes" file. Bryophytes were identified to functional groups only, so no additional identification work is required.

F. Lichen trace species.

Lichen species from the "walk-around" search for trace species are stored in two places: 1) the species which were identified with certainty in the field are listed on paper field forms. Taxa of uncertain identity were collected and the field packets are the record of their occurrence. The former list was compiled from a dropdown choice list and can be appended into the database directly after addition of necessary plot identifying information. After identification of the collected species becomes available, they may be entered either by use of a dropdown choice list as in the field spreadsheets, or, if there are numerous specimens, by entering codes using the "compact" data format followed by conversion to the "list" (database) format (see Appendix C, SOP #4, part C). After merging of these two data sources for trace species, lists should be error checked against the species identification plot lists, assigned the default value indicating "trace" (0.01), and appended into the database.

Appendix D Literature cited

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